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VOLUME VIII
LIFE SCIENCES

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

PREFACE

The purpose of the preliminary edition of the "Reference Earth Orbital Research and Applications Investigations" set forth in this document is to:

a. Provide criteria, guidelines, and an organized approach for use in the Space Station and Space Shuttle Program Definition Phase and ancillary studies in designing a flexible, multidisciplinary orbiting space facility and logistics system.

b. Define a manned space flight research capability to be conducted in earth orbital Space Stations and Shuttles.

c. Provide a basis for potential follow-on programs.

The term "Functional Program Element" (FPE) used in this document describes a gross grouping of experiments characterized by the following two dominant features:

a. Individual experiments that are mutually supportive of a particular area of research or investigation, and

b. Experiments that impose similar and related demands on the Space Station Support Systems.

The research and applications investigations as set forth herein depart from a heterogeneous collection of individual experiments and are designed toward a "research facility" and "module" approach. The term FPE and "module" are used somewhat interchangeably in this publication although this relationship is unintentional. Thus, a particular FPE may be described which does not fully utilize the capability of a complementary module but would, however, permit flexibility in experiment planning.

Functional Program Elements and experiments covered in this document are envisioned for flight with the initial Space Station and the Space Shuttle. Only those FPE's and experiments which can reasonably be expected to be accomplished during the first few years of the Space Station and Space Shuttle have been described in detail in this document. However, for the most part, these FPE's are considered to be open-ended so that their utility could be extended.

This publication is applicable to all NASA program elements and field installations involved in the Space Station and Space Shuttle program.

The supply of this document is limited. Therefore, for those procurement actions involving only a certain portion (or portions) of this handbook, the cognizant NASA installations shall abstract from this handbook only such portions as apply to a given RFP or contract action.

This publication was prepared in conjunction with NASA Headquarters Program Offices and field installations involved in payload planning and with industry participation. It is an updated and revised version of the Candidate Experiment Program for Manned Space Stations, NHB-7150.xx, dated September 15, 1969 and the changes thereto dated June, 1970. These earlier versions are hereby cancelled.

The material contained in each volume has been produced under the guidance of Review Groups composed of scientific personnel at NASA Headquarters, MSFC, LaRC, MSC, LeRC, GSFC and ARC. The purpose of this effort was not only to revise and update the experiment programs but also to establish the Space Shuttle as well as the Space Station requirements.

Volume I, Summary, presents the background information and evolution of this document; the definition of terms used; the concepts of Space Shuttle, Space Station, Experiment Modules, Shuttle-sortie Operations, and Modular Space Station; and in Section IV, a summary of the Functional Program Element (FPE) requirements is presented.

Volumes II thru VIII contain detailed discussions of the experiment programs and requirements for each discipline. The eight volumes are:

Volume I	Summary
Volume II	Astronomy
Volume III	Physics
Volume IV	Earth Observations
Volume V	Communications/Navigation
Volume VI	Materials Sciences & Manufacturing
Volume VII	Technology
Volume VIII	Life Sciences

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VOLUME VIII

LIFE SCIENCES

INTRODUCTION

PART A

GOALS AND OBJECTIVES

The NASA Life Sciences Program encompasses all of the individual program areas covering:

a. Medical and behavioral questions associated with manning and operating an Earth-orbital research facility or facilities.

b. Development, testing, and incorporation into such facilities of the advanced technology for life support and protective systems.

c. Fundamental biological and biomedical research.

The various program elements and their support requirements are identified in Functional Program Elements (FPEs) 1 through 7. The program as defined is a "candidate" program. Individual experiments identified are thus not necessarily the precise experiments that ultimately will be conducted. They are, however, representative examples of the types of research activities that will be carried out. The candidate research (experiment) program provides sufficient details of research equipment requirements, man functions, and spacecraft impacts to characterize the full research capability needed to implement a broad-based, evolving life sciences research program. In all cases representative experiments are based on one or more of the following:

a. Potential problems identified by observations during earlier flight.

b. Recommendations by competent scientific review bodies identifying potentially fruitful (if not critical) problem areas.

c. Recommendations of scientific review bodies considering formal scientific flight-experiment proposals.

The most effective pursuit of this program depends upon a Life Sciences Space Laboratory consisting of:

a. A matrix of common operations research equipment/facilities (CORE) serving a broad spectrum of experimental areas in several FPEs.

b. Supplemental facilities and instrumentation relating to a smaller number of FPE's or experiments, but which are sufficiently specialized to be removed from CORE.

c. FPE or experiment-peculiar items ancillary to one or both of the preceeding more general categories. (See Figure 1.)

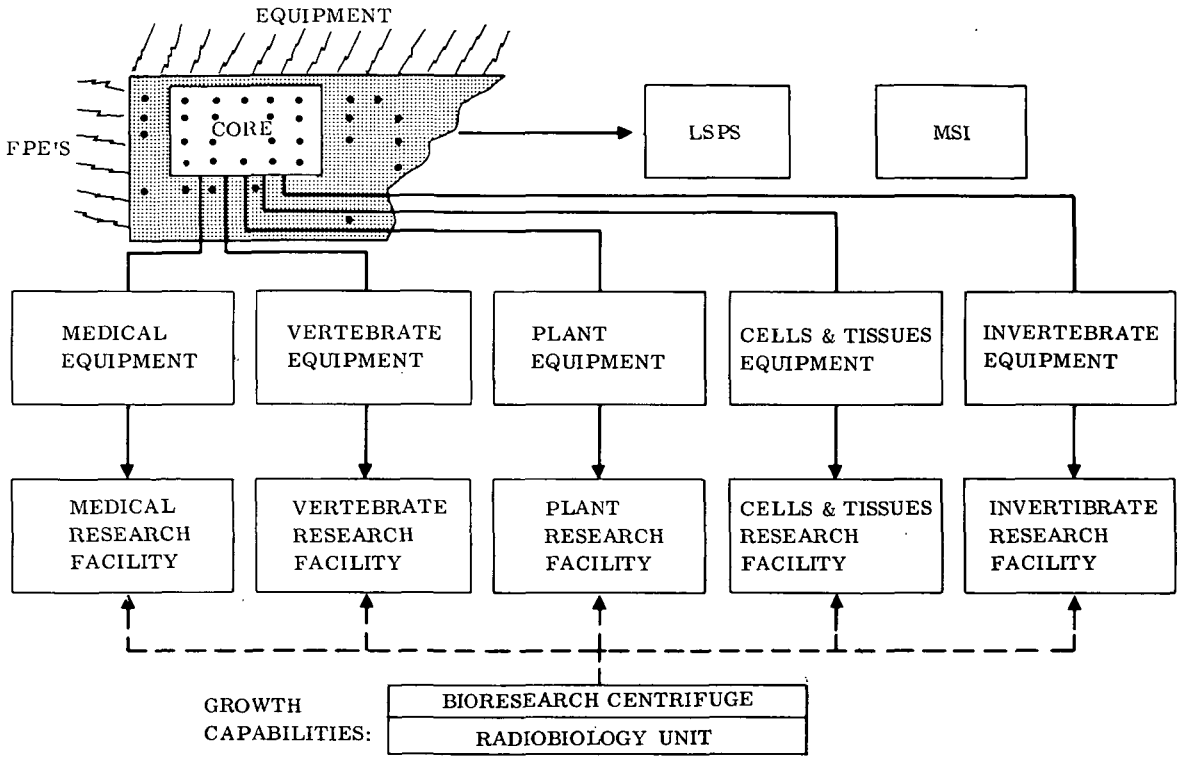


Figure 1. Life Sciences Facility Approach

The composition of the CORE units is defined by the collective FPE requirements and is described in Part B of this Introduction. Reference is made to appropriate CORE units or specific items in the individual FPEs. In this way, unnecessary repetition is avoided and the problem of collecting or factoring out summated data such as power, weight, volume, etc, for design or payload planning is simplified.

While the FPE elements are essentially self-contained units, a considerable interrelationship exists among them, in terms of both implementation and objectives. For example, all elements involving biochemical or microscopic examination of samples would, insofar as practicable, utilize common laboratory facilities and would be directed toward the understanding of the effects of the space environment on fundamental processes or structures, regardless of the species of the test subject.

In the execution of the research programs, it is anticipated that the number and type of experiments being carried out at any one time would be consistent with the mission mode, capabilities and limitations of the spacecraft facilities, and with an orderly sequencing of experiments based upon previous experience and the identification of new and significant problems. Thus, for planning purposes, it would be inappropriate to arbitrarily program the conduct of a total single FPE in a predetermined period of time. Some of the individual experiments may be concluded after one or two tests while others in the same FPE may require extensive periods of study.

Further, the total facilities are not considered on an "all-or-none" basis. In a mission involving a Shuttle Sortie, for example, only those elements of the CORE or specialized instrumentation required for payload support would be flown. Long-lead-time items not available during earlier missions could dictate late scheduling of certain experiments without serious impact on the overall program. Those experiments for which facilities and instrumentation are available early would be scheduled first.

It is also planned to utilize a "team approach" wherever possible in the research programs. With this approach, the maximum amount of data may be obtained from a single group of experimental subjects, thus simplifying logistics, minimizing the total number of specimens required, and simplifying the correlation of data. These factors must be considered in detailed flight-schedule and operations planning.

The objective of the CORE and these FPEs is, therefore, to provide a facility (or facilities) capable of supporting the described program elements and providing the flexibility for in situ modifications of experiment protocols and the introduction of yet undefined experiments with a minimum of impact on budget, flight schedules, or facility modification.

While the FPEs are intended as engineering and operational reference data for all manned missions, certain experiment modules may be flown unmanned (Shuttle launched and recovered or Space Station modules in the detached mode). Apparatus or instrumentation designed for use in manned vehicles may not be suitable in these totally or near totally automated missions.

Subsequent sections of this volume contain tabular summaries which refer to crew skills by code number. Table 1 lists skills and code numbers used in all volumes of this document.

A.1 BIOMEDICINE

The primary objective of the Biomedical Program is the qualification of man for extended space missions. This naturally entails a thorough understanding of his physiological and behavioral responses to long-duration flights as well as ascertaining his ultimate performance capabilities. The secondary objective, which will take on ever increasing importance as the first objective is achieved, is to gain in-depth knowledge of man's psychophysiological responses to the space flight environment, including the null or reduced gravity state, heavy particle radiation, etc, and the application of this knowledge to conventional clinical medicine and practice. For this program to yield the utmost information for the benefit of man requires not only a deliberate and progressive ground-based and flight research program, but also close cooperation with, and understanding of, the goals and objectives of the other elements comprising the overall Life Sciences Program.

Table 1. Crew Skills

Code No.	Title	Code No.	Title
1	Biological Technician	14	Optical Technician
2	Microbiological Technician	15	Optical Scientist
3	Biochemist	16	Meteorologist
4	Physiologist	17	Microwave Specialist
5	Astronomer/Astrophysicist	18	Oceanographer
6	Physicist	19	Physical Geologist
7	Nuclear Physicist	20	Photo Geologist
8	Photo Technician/ Cartographer	21	Behavioral Scientist
		22	Chemical Technician
9	Thermodynamicist	23	Metallurgist
10	Electronic Engineer	24	Material Scientist
11	Mechanical Engineer	25	Physical Chemist
12	Electromechanical Technician	26	Agronomist
13	Medical Doctor	27	Geographer

Biomedical experiments and observations will be accomplished primarily on man during ground-based and flight research activities. However, non-human test subjects may be utilized, particularly if they afford a more definitive answer to a question of biomedical significance or if the experimental procedure is likely to be hazardous for man.

Within the framework of the Life Sciences volume and its several FPEs, the Biomedical Program will primarily utilize the facilities and encompass the programs described in FPE's 1 (Medical Research Facility), 6 (Life Support and Protective Systems), and 7 (Manned System Integration). Additional elements or components from the other Life Sciences FPEs will be used as necessary to accomplish an integrated, timely, and meaningful research program.

A.2 SPACE BIOLOGY

The Space Biology (Bioscience) Program is described in FPEs 2 through 5. Overall goals and objectives of the program are to:

a. Understand the role of gravity in life processes and the capability of living organisms to adapt to gravitational changes.

b. Understand the role of time in biology, including the effects of time-varying environmental parameters on biological rhythms and aging.

c. Determine the potential applications and develop the techniques to utilize new biological advances in theory and space technology to advance medicine, biology, public health, agriculture, and space exploration.

To adequately satisfy these goals and objectives, it is necessary to study a wide variety of life processes and functions on a broad spectrum of organisms to establish interspecies relationships in response to the space environment as well as to understand the response per se.

It is planned to follow the ground-based research practice of utilizing the most appropriate experimental subjects for the investigation of specific phenomena. The most appropriate subject is usually the one for which a considerable baseline of information exists in regard to a particular type of study.

Since the relative cost of research in space is high as compared to that on Earth, and the facilities limited, maximum utilization of test subjects is planned. This involves a team effort in which the maximum number of observations or tests feasible and practicable will be carried out on any one group of subjects. However, discretion must be exercised to ensure that no one set of observations is prejudiced or compromised by the introduction of another experimental procedure.

In the statement of goals and objectives the scalar, time, is specifically noted since all biological processes are normally sequenced or cycled in accord with some fractional or whole-number multiple of geophysically or astronomically related events such as the day-night cycle, tides, seasons, etc. While the role of these events in the maintenance of biological integrity is not understood or even an established fact, there is a correlation in time between many cyclic biological variables and geophysical environmental variables. In space flight, the usual environmental factors may vary in frequency or magnitude (e.g., 90 min./rev. as opposed to 24 hr.) or may be essentially nonexistent. The possibility of an effect cannot be overlooked in experiment planning.

It is an established fact that the response of living systems to multiple stress factors is quite varied and often unpredictable. Some combinations of variables (such as pO_2 and ionizing radiation, pO_2 and vibration, drugs and motion, etc.) may have cancelling, additive, or synergistic relationships. For this reason, it is desirable to control the number of variables departing from their normal values in examining the effects of a single one. Biologists have therefore determined that the initial space flight experiments should be conducted in an Earth-atmosphere gaseous environment with weightlessness (or a controlled level of acceleration) as the only planned variable. Where possible, paired experiments involving variation of two factors (such as weightlessness and radiation) will be planned.

The four space biology FPEs are organized around species with more or less common facilities requirements beyond those provided by the CORE. However, for scheduling and operations, it would be advantageous to group experiments to make maximum utilization of crew skills and equipment operating or available at any given point in time. Early scheduling should also consider factors such as potential for contributing directly to long-term manned flight capability.

As pointed out above, no operating plan should call for flying a single, total space biology FPE experiment program as a separate entity with all of the goals and objectives satisfied within a predetermined period of time.

A.3 LIFE SUPPORT AND PROTECTIVE SYSTEMS

The goals in Life Support and Protective Systems may be generally stated as the acquisition of engineering data for advanced design of components and subsystems, and will require experimental results in the following areas:

a. Effects of long-term zero-g on physiological factors on which life support design requirements are based.

b. Effects of zero and reduced g on physical and chemical phenomena of life support processes.

c. Performance parameters of components in zero-g.

d. Reliability and maintainability of components for long durations in zero-g.

A further discussion of these goals is contained in Paragraph 6.1.

A.4 MAN-SYSTEM INTEGRATION

The overall objective in Man-System Integration is to provide qualitative and quantitative data relative to crew operations and equipment design for various elements of space vehicles. Experiments will use a combination of FPE and experiment-unique

equipment along with onboard equipments. Some of the data gathering will be performed on an ad lib basis. A crew member trained in behavioral science will serve as the experiments test conductor and onboard data analyst. A further discussion of the goals and objectives in man-system integration is contained in Section 7.1.

PART B

PHYSICAL DESCRIPTION OF CORE AND NON-CORE MULTIPURPOSE UNITS

The Life Sciences Laboratory is to be a general facility to support manned research in the seven areas described in the FPEs. This section deals with the CORE and certain non-CORE multipurpose units. The CORE contains the basic common equipment to support comprehensive Life Sciences research. Additional equipment specific to an FPE is described in the respective FPE section. In a third category are some equipment units which are shared by two or more FPEs but are not part of the CORE, viz., the Bioresearch Centrifuge, the Radiobiology Unit, and the Airlock/EVA Capability Unit. Functions of units excluded from the CORE may be high priority tasks but the necessity for their special design and fabrication will depend upon spacecraft design and operational modes. For example, if the spacecraft's primary electrical power source is a nuclear reactor, this might serve as an onboard source for exposing biological material to known dose rates of ionizing radiation; if a section of the spacecraft rotated to produce acceleration levels up to 1.0 g, need for a large centrifuge could be obviated. These capabilities are required for the most comprehensive approach to research; however, a wide variety of priority research can be accomplished without them.

Two required functions, waste disposal and separate experiment environmental control systems, are not provided here. Experiment wastes, such as animal residues and disposable instruments, do not appear to present any unique problems and may be included in the general waste management system provided it has sufficient capacity. Some chemical reagents and radioisotopes will require special handling. In the ECS, it is considered necessary to isolate the experiment systems from the general crew environment.

Equipment units are groups of hardware items for related functions. The inventory of equipment items and the packaging of an equipment unit must be determined with full consideration of experiment requirements, man-system integration, and the laboratory layout. An equipment unit may be one console containing the equipment inventory or it may be many small consoles positioned appropriately throughout the laboratory. In some cases the equipment will be operationally distributed at the specimen holding sites. Cameras, for example, are assigned to the Visual Records and Microscopy Unit but are used with several other units, including the Plant Holding Unit.

Laboratory layouts for Life Sciences must be done with caution because of the very high interaction of man and specimens, and the extensive involvement of man in research operations. Consideration must be given to distribution of the measurement-equipment units throughout the various specimen holding units versus the general configuration of one area of measurement-equipment units and another area for specimen holding.

The equipment units are envisioned as rack and module systems with high-level commonality and interchangeability. Modules will be of standard sizes with standard electrical plugs and plumbing connectors.

B.1 LIFE SCIENCES COMMON OPERATIONS RESEARCH EQUIPMENT (CORE)

The CORE is comprised of seven equipment units basic to the performance of the Life Sciences FPEs: a) Visual Records and Microscopy, b) Data Management, c) Life Sciences Experiment Support, d) Preparation, Preservation, and Retrieval, e) Biochemical and Biophysical Analysis, f) Maintenance, Repair, and Fabrication, and g) Ancillary Storage.

The functional capability of each equipment unit is provided once in a given spacecraft and will be time-shared by the FPEs. Functional redundancy is required only when the requirements for that function exceed reasonable full-time demand. Greater equipment demand inherent in crews of two or more experimenters may be reduced by scheduling work shifts. Fewer equipments reduces weight and volume and tends to normalize power. Sizing of the console or consoles for each equipment unit should be done with consultation and direction from the NASA Life Sciences Review Group.

Figure 2 shows the current organization of FPEs and equipment units of the Life Sciences Discipline. Required equipment units are listed across the top, and an X in line with an FPE indicates use of the equipment unit for one or more experiments of that FPE. Equipment units identified in the CORE meet two criteria. First, there is a high degree of commonality with respect to use in a number of FPEs. Second, the requirement is basic to the research program. Some other equipments, such as the radiobiology unit and the bioresearch centrifuge, have a high degree of commonality but are considered growth items. The CORE is identical in the first five FPEs, and portions of it are used in the LSPS and MSI FPEs.

B.1.1 VISUAL RECORDS AND MICROSCOPY UNIT. Visual Records and Microscopy Unit capabilities include still photography, cinematography, television, hard records, oscilloscope display/readout, electronic imaging, microscopic observations and records, micromanipulation, and microscope dissecting. Some equipment items representative of these capabilities are illustrated in Figure 3.

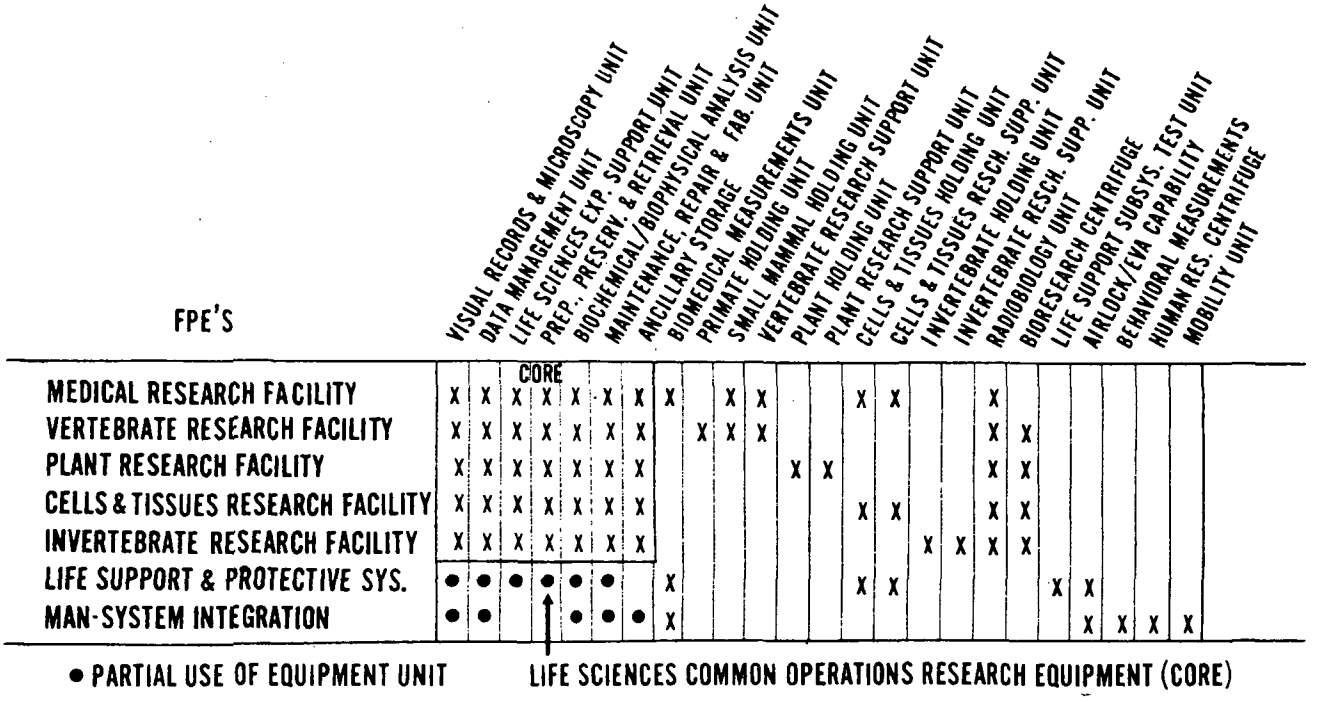


Figure 2. Life Sciences Equipment Units

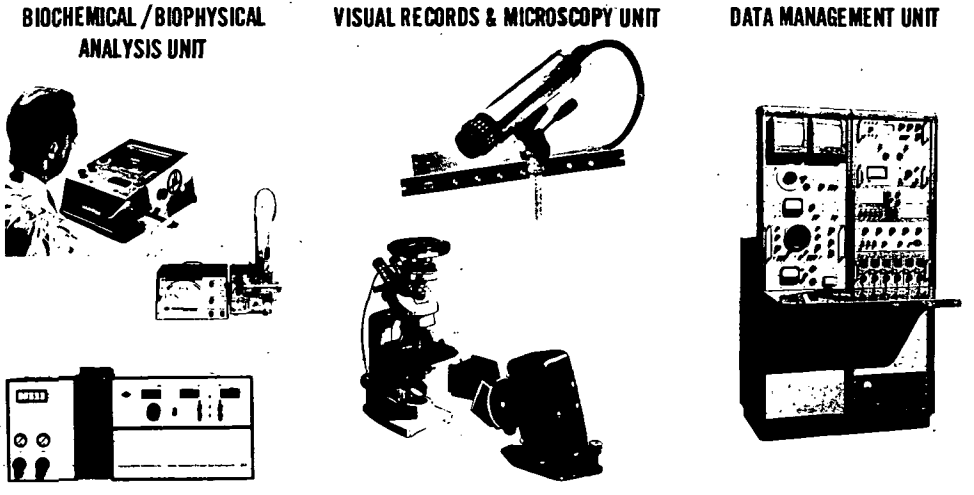


Figure 3. Life Sciences CORE: Analysis, Measurements and Data

B.1.1.1 Functional Capability. Detailed functional requirements are:

a. Still Photography
 1. Polaroid
 2. 35 mm color

b. Cinematography
 1. Time lapse
 2. High speed
 3. Standard

c. Hard Records: Strip charts

d. Oscilloscopic Display/Readout
 1. Standard CRT
 2. Persistent CRT

e. Television and/or Video Tape
 1. High resolution color
 2. Black and white

f. Electronic Imaging (may be TV): Holography

g. Microscope Dissecting: Binocular Stereo; 2-200 magnification

h. Micromanipulation: Microanalysis Tool Kit

i. Microscopy
 1. Light; 10-1000 magnification
 2. Phase contrast; 10-1000 magnification
 3. Interference contrast; 10-1000 magnification
 4. Fluorescence; 10-1000 magnification
 5. Dark field; 10-1000 magnification
 6. Binocular stereo; 2-200 magnification

j. Microscopic Records
 1. Still photo (color)
 2. Cine
 3. TV (color); Direct viewing or taped for transmission

B.1.1.2 Description. This equipment unit is a rack and module system with associated work tables. The rack and module system is standardized to a minimum number of module chassis sizes with a high degree of interchangeability of each size module. For example, adjacent to the work table is a module rack with maximum access for the investigator. One experiment may require an oscilloscope display and another experiment a strip chart recorder. The modular design provides capability to exchange the two display units. The electronic patch-panel system described in Section B.1.2 of the core provides signal routing to and from these units.

In addition to the rack and module system is a system of cameras, TV and cinematographics, each requiring a storage area as part of this equipment unit. The storage area consists of cabinets for camera storage and a drawer system for camera accessories. Camera accessories include various lenses and lens systems, camera commutation systems, optical commutation systems, films, and tapes. General trends are toward electronic imagery and minimal film records. The camera inventory is minimized by standardization of camera types and record requirements. Records are required of specimens in visible light as well as attenuated light or "dark" periods. One camera can record under both conditions with selected optical conditioning and electronic and film image-enhancement techniques. The television coverage required for most organisms is high quality time-lapse black and white. Color TV requirements are minimal and should be reserved for ad hoc observations and microscopy.

The visual records work area will contain a CRT display for analog records, digital records, and video records, a work bench and a cell counter. The work bench requires laboratory supplies, vacuum, power, and air and hardware storage. The microscopes contain many accessories which also must be stored. Associated with microscopy is the microanalysis tool kit, including the micromanipulator.

Table 2 lists pertinent characteristics for equipments in the Visual Records and Microscopy Unit. Table 3 is an equipment unit summary.

Table 2. Equipment List for Visual Records and Microscopy Unit

Name	Performance Characteristics	PWR (W)	WT kg (lb)	VOL m^3 (ft^3)
Movie Camera	35 mm film; frame rates 1/hr to 20/sec	0	0.5 (1)	8.5×10^{-3} (0.3)
Plate Film Camera	Std. 82.55 × 192.95 mm (3.25 × 4.25 in.)	0	1.25 (2.75)	1.05×10^{-3} (0.037)

Table 2. Equipment List for Visual Records and Microscopy Unit (Continued)

Name	Performance Characteristics	PWR (W)	WT kg (lb)	VOL m^3 (ft^3)
Polaroid Camera (4 Reqd)	Std. 82.55 × 192.95 mm (3.25 × 4.25 in.)	0	1.25 (2.75)	1.05×10^{-3} (0.037)
Roll Film Camera (Accessory; close-up optics compatible with microscopes)	35 mm	0	2.3 (5)	2.8×10^{-3} (0.1)
Video Camera	Commercial color	100	22.5 (50)	28.3×10^{-3} (1)
Video Camera (Weight and volume includes camera controller. Up to 50 units required; assume 40.)	Standard B&W	25	4.54 (10)	11.3×10^{-3} (0.4)
		1000	181.6 (400)	0.453 (16)
Voice Recorder	TBD	50	2.3 (5)	0.25 (8.5)
Holograph	TBD	500	115 (250)	5.3 (186)
Micromanipulator	TBD	0	2.3 (5)	0.18 (5)
Console and Rack	TBD	0	204 (450)	0.6 (20) (Incl. unusable space)
High-Speed Oscillograph Recorder	Chart Speed 1 to 500 mm/sec Sensitivity 0.1 to 50 mV/mm Freq. dc - 1000 Hz	1000	9.1 (20)	42.4×10^{-3} (1.5)
Compound Microscope with camera attachment & accessories for dark field,	Eyepieces: 10X, 20X. Objectives: 25X, 40X, 100X	25	4.5 (10)	14.1×10^{-3} (0.5)

Table 2. Equipment List for Visual Records and Microscopy Unit (Continued)

Name	Performance Characteristics	PWR (W)	WT kg (lb)	VOL m^3 (ft^3)
polarized light, phase contrast, interference contrast and fluorescence microscopy				
Stereoscopic dissecting microscope	2.5X to 100X at 80 mm working distance, 5X to 200X at 28 mm working distance	30	13.6 (30)	28.3×10^{-3} (1)

Table 3. Equipment Unit Summary

	Laboratory Only	Laboratory + Centrifuge
OPERATOR SKILL	TBD	TBD
POWER, AC		
average, watts	1000	1000
peak, watts	1000	1000
peak duration, hr/day	NA	NA
POWER, DC		
average, watts	1450	2250
peak, watts	1450	2250
peak duration, hr/day	NA	NA
WEIGHT, kg (lb)	543 (1200)	634 (1400)
ENVELOPE		
volume, m^3 (ft^3)	1.3 (45)	1.6 (55)
height, cm (in)	TBD	TBD
width or diam. cm (in)	TBD	TBD
depth, cm (in)	TBD	TBD

Table 3. Equipment Unit Summary (Continued)

	Laboratory Only	Laboratory + Centrifuge
DATA		
voice, hr/day	8	16
TV, B&W, hr/day	24 (1 ch.)	24 (2 ch.)
TV, color, hr/day	2	4
analog, MHz	4 (TV)	4 (per TV ch.)
digital, bps	none	none

B.1.2 DATA MANAGEMENT UNIT. The Data Management Unit functional capabilities include data storage, experiment management, subsystem control, electrophysiological and electromechanical transducer support, signal analysis and display, and crew experiment task guidance. Some equipment representative of these capabilities is illustrated in Figure 3.

B.1.2.1 Functional Capability. This equipment unit is comprised of six major functional areas:

a. Data Storage, consisting of raw data storage until processed or evaluated and the requirement for the raw data is eliminated. Raw data of interest and processed data are stored until the next available downlink. Equipment items are:

 1. Magnetic Disc or Tape
 2. Memory Bank

b. Experiment Management, which is control of all automatic functions at the specimen holding sites:

 1. Light Control
 2. Camera Commutation
 3. Camera Operation
 4. Electrophysiological Commutation
 5. Feeding and Watering
 6. Specimen Waste Management (within holding unit to manifold)

c. Subsystem control, automatic ECS analysis, specimen waste processing, etc.:

1. ECS Operation
2. Specimen Waste Management System (manifold to storage and processing, etc.)
3. ECS Analysis
4. Environmental Sampling

d. Electrophysiological and Electromechanical Transducer Support. This is a rack and module system with very high commonality and interchangeability of electronic plug-in modules designed for use at the holding units or analysis units. The transducers are experiment peculiar equipments and not part of this unit:

1. Signal Conditioning
2. ENG
3. EEG
4. ECG
5. EMG
6. Phonocardiogram
7. Strain Gauges
8. Thermistors
9. Thermocouples
10. Automatic Blood Pressure
11. Respiration Rate

e. Signal Analysis and Display. As required, raw data must be processed and displayed to the investigator for experiment status. Raw data must be displayed to the investigator at the work site simultaneously with processed data:

1. X-Y Plots of Trends
2. CRT Analog & Digital Display
3. Data Compression
4. Signal Averaging
5. Wave Form Analysis

f. Crew Task Guidance. A computerized step-by-step instruction for crew operational capabilities is listed for each function:

1. Instructs Crew for Mission Protocol.
2. Provides Procedures for Observation/Measurements.

3. Indicates Experiment Protocol Options as a Function of Observation/ Measurement Results. (This function could be handled by direct communications with the Principal Investigator.)

4. Provides Experiment History Data to Crew.

5. Receives Uplink Data from Ground Experiment Protocol Redirect

B.1.2.2 Description. This is the main experiment data management system. It consists of the data management computer, a comprehensive electronic manifold system with two patchboard levels (at the computer and at a series of patchboards positioned appropriately throughout the equipment units), and the signal conditioners at the specimen handling site. The patchboards are specifically required at the specimen holding equipment units. A maximum electronic capability (power, experiment control signals, and data signals) is required at each specimen holding site; however, an average requirement from a large number of specimen holding sites may be 50 percent of maximum. Similarly, the experiment control may be required at five instruments simultaneously. The patchboard provides for a maximum use of a minimum number of data channels by patching into only the required data channels for maximum capability at the holding sites and operating the five instruments from a single signal via a patchboard bus.

Each holding site will have a rack and module system, which is described as part of this unit. Biological signals are generally very high impedance and require signal conditioning at or near the source. Standardized electronic modules to perform the signal conditioning and to provide the specific transducer circuitry are required at specimen holding racks. Typically, the electronic modules will support the transducer and measure ECG, EEG, EMG, specimen activity, strain gauge output, specific ion electrodes for pCO_2, pO_2, pH_2O, etc., pressure, and temperatures.

Table 4 lists pertinent characteristics for equipments in the Data Management Unit. Table 5 indicates data requirements. Table 6 is an equipment unit summary.

Table 4. Equipment List for Data Management Unit

Name	Performance Characteristics	PWR Watts	WT kg (lb)	VOL m^3 (ft^3)
Experiment Support System Console	Experiment Operations Controls Instrument Time Sharing Stores Data Preliminary Data Processing	300	90 (200)	850 (30)
Signal Conditioner (Plug-in Module) ECG	0-40 Hz; Sensitivity 100 μV fullscale; AC Notch Filters at Power Supply Freq.	0.1	0.23 (0.5)	3×10^{-4} (0.01)
Signal Conditioner (Plug-in Modules) EEG	0-100 Hz; Sensitivity 100 μV full scale; AC Notch Filters at Power Supply Freq.	0.1	0.23 (0.5)	3×10^{-4} (0.01)
Signal Conditioner (Plug-in Module) EMG	0-100 Hz; Sensitivity 100 μV full scale; AC Notch Filters at Power Supply Freq.	0.1	0.23 (0.5)	3×10^{-4} (0.01)
Signal Conditioner - Strain Gage Coupler	DC to 150 Hz; Sensitivity 100 μV full scale	0.1	0.23 (0.5)	3×10^{-4} (0.01)
Signal Conditioner (Plug-in Module) Heart Rate Monitor	0.2 mV 30 bit/min to 400 bit/min	0.1	0.23 (0.5)	3×10^{-4} (0.01)

Table 5. Data Requirements

MEASUREMENT	DATA ACQUISITION				DATA MANAGEMENT			DATA DISPOSITION						
											DUMP REQUIREMENTS			
	TYPE	ANALOG BANDWIDTH OR DIGITAL CHARACTERS PER MEASUREMENT	MEASUREMENT DURATION (AVERAGE)	TYPICAL NO. OF MSMTS. PER DAY PER SPECIMEN	DISPLAY	PROCESSING	STORAGE FOR EARTH RETURN	STORAGE, %	DUMP, %	TYPE	CONTINUCUS	EACH ORBIT	DAILY	NOTES
Atmospheric Gases pO_2, pN_2, pCO_2, pCO, pNH_3	D	3	Continuous	5(1)	Numeric & CRT	XY Plot	Short Term	1	1(2)				X	(1) Cage rack level. (2) Transmit out-of-limits data only.
Relative Humidity	D	2	Continuous	5(1)	Numeric & CRT	XY Plot	Short Term	1	1(2)				X	(1) Cage rack level. (2) Transmit out-of-limits data only.
Ambient Temperature	D	2	Continuous	5(1)	Numeric & CRT	XY Plot	Short Term	1	1(2)				X	(1) Cage rack level. (2) Transmit out-of-limits data only.
Illumination	D	4	Continuous	5(1)	Numeric & CRT	XY Plot	Short Term	1	1(2)				X	(1) Cage rack level. (2) Transmit out-of-limits data only.
Centrifuge Rate	D	2	Continuous	24(3)	Numeric & CRT	None	Short Term	1	1(2)				X	(3) Centrifuge level.
Urine Analysis (4)	D	3	--	12	Numeric & CRT	XY Plot of Trends	Short Term	0	100				X	(4) One analysis = 6 parameters (2 analyses/day)
Blood Gases pO_2, pCO_2, pH	D	3	--	3	Numeric & CRT	None	Short Term	0	100			X		
O_2 Consumption	D	3	Continuous	1	Numeric & CRT	XY Plot	Short Term	0	100			X		
CO_2 Production	D	2	Continuous	1	Numeric & CRT	XY Plot	Short Term	0	100			X		
Plant Growth (Strain Gages)	D	3	Continuous	1	Numeric & CRT	XY Plot	Short Term	0	100				X	
ECG	A	0-40 Hz	2 min.	12	CRT	Heart Rate, Waveform Analysis	Short Term; Retain Out-of-Limits Data	1	10(2)	D		X		
Blood Pressure	D	6	--	6	Numeric	Limit Compression XY Plot	Short Term	10	50(2)	D		X		

Table 5. Data Requirements (Continued)

MEASUREMENT	DATA ACQUISITION				DATA MANAGEMENT			DATA DISPOSITION						
											DUMP REQUIREMENTS			
	TYPE	ANALOG BANDWIDTH OR DIGITAL CHARACTERS PER MEASUREMENT	MEASUREMENT DURATION (AVERAGE)	TYPICAL NO. OF MSMTS. PER DAY PER SPECIMEN	DISPLAY	PROCESSING	STORAGE FOR EARTH RETURN	STORAGE, %	DUMP, %	TYPE	CONTINUOUS	EACH ORBIT	DAILY	NOTES
Respiration Rate	D	2	--	6	Numeric	XY Plot		10	50	D		X		
EEG	A	0-100 Hz	2 min.	12	CRT	Waveform Analysis		1	10	D		X		
EMG	A	0-100 Hz	2 min.	12	CRT	Waveform Analysis		1	10	D		X		
Animal Activity	A	0-40 Hz	Continuous	--	CRT	Correlation with Stimuli History XY Plot		0.1	0.1(5)	D		X		(5) Dump high-activity data as determined by XY plot, and select periods of stimulation and all trend data.
TV	A	4 MHz	2 min.	48	CRT	None	Video Tape Short Term	100	1	A		X		
Food Intake	D	3	--	4	Numeric & XY Trends	XY Plot of Trend	Short Term	0	100	D			X	
Feces Mass	D	3	--	1	Numeric & XY Trends	XY Plot of Trend	Short Term	0	100	D			X	
Blood Chemistries	D	3	--	4	Numeric & XY Trends	XY Plot of Trend	Short Term	0	100	D			X	
Body Temperature	A	2	--	12	Numeric & XY Trends	XY Plot of Trend	Short Term	0	100	D		X		
Thermal Output	D	2	Continuous		Numeric & XY Trends	XY Plot	Short Term	0	100	D			X	
Radiation	D	3	Continuous			Unit Compression XY Plot				D			X	
Event Activation/Termination	D	1	--	4	Numeric	None	Short Term	0	100	D			X	
Noise	A	50-30 Khz	Continuous	One per cage rack	--	Cyclic Correlation. Freq. Evaluation XY Plots of Select Freq. Ranges	Short Term	1	1(6)	D				(6) Dump out of limits or any unusual data.

Table 5. Data Requirements (Continued)

MEASUREMENT	DATA ACQUISITION				DATA MANAGEMENT			DATA DISPOSITION						
	TYPE	ANALOG BANDWIDTH OR DIGITAL CHARACTERS PER MEASUREMENT	MEASUREMENT DURATION AVERAGE	TYPICAL NO. OF MSMTS. PER DAY PER SPECIMEN	DISPLAY	PROCESSING	STORAGE FOR EARTH RETURN	STORAGE, %	DUMP, %	TYPE	DUMP REQUIREMENTS			NOTES
											CONTINUOUS	EACH ORBIT	DAILY	
Vibration	A	0-100 Hz	Continuous	One per cage rack	--	Cyclic Correlation	Short Term	1	1	D			X	(6) Dump out of limits or any unusual data.
Acceleration	A	0-10 g	Continuous	One per cage rack	Chart Recorder	Cyclic Correlation	Short Term	100	1	D		X		
Miscellaneous	D	3	--	0.5	Numeric	None	Short Term	100	100	D		X		

Table 6. Equipment Unit Summary

	Laboratory	Laboratory + Centrifuge
OPERATOR SKILL	TBD	TBD
POWER, AC		
average, watts	300	300
peak, watts	350	350
peak duration, hr/day	TBD	TBD
POWER, DC		
average, watts	200	220
peak, watts	200	220
peak duration, hr/day		
WEIGHT, kg (lb)	227(500)	236(520)
ENVELOPE		
volume, m^3 (ft^3)	1(35)	1.1(40)
height, cm (in.)	TBD	TBD
width or diam, cm (in.)	TBD	TBD
depth, cm (in.)	TBD	TBD
DATA		
voice, hr/day	16	16
TV, B&W, hr/day	NA	NA
TV, color, hr/day	NA	NA
analog, MHz	NA	NA
digital, bps	100	200

B.1.3 LIFE SCIENCES EXPERIMENT SUPPORT UNIT. This unit has the primary function of a supply and services interface between the space vehicle and Life Sciences equipment units. The concept is illustrated in Figure 4.

B.1.3.1 Functional Capability. The unit provides for transfer, distribution, control, and conditioning as required for electrical and fluid utilities, including:

a. Electrical power

b. Hard-line data transfer

c. Vacuum

d. Water

e. Purge and pressurant gases

f. Process gases

g. Thermal control fluids

h. Time signals, alarms, and other special communications.

B.1.3.2 Description. The unit will consist of a console and/or panel containing equipment items to perform the functions named. Input connections will be from the spacecraft subsystems, and multiple output connections will be to CORE equipment, to FPE-peculiar units, and to experiment-peculiar units as required. The several electrical circuits will include on-off controls and circuit protection, and may include conditioning of voltage, frequency, and/or waveform. Such conditioning will be

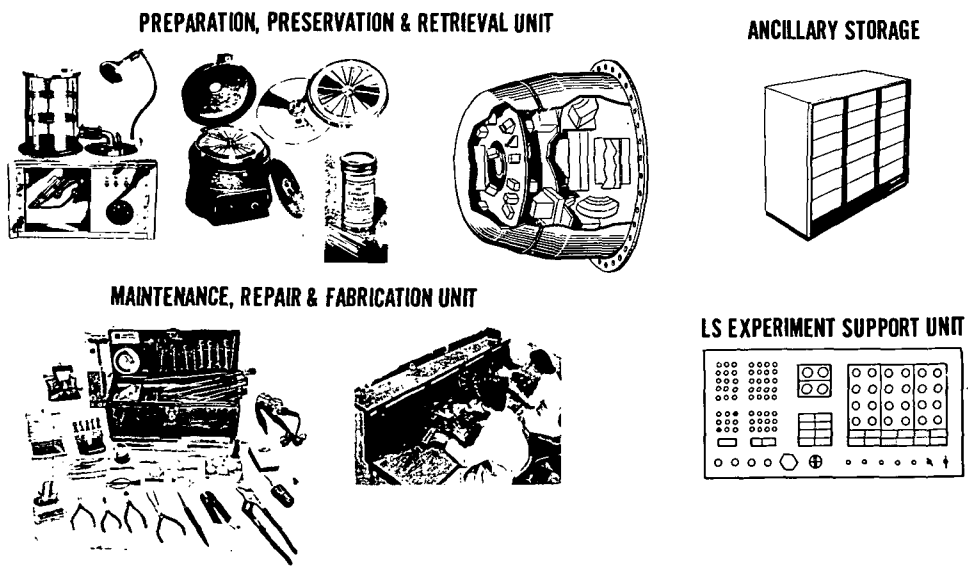


Figure 4. Life Sciences CORE Services

determined by user equipment requirements and by optimization analyses which may show advantages for conditioning only at the experimental level or equipment item level. The liquid and gas circuits will have on-off controls, adjustable pressure regulation, and flow control.

Flexibility in distribution will be through multiple connections, manifolding, and switching for applications of extended usage, and by a patchboard concept for more temporary usage. The patchboard will be used with suitable plug-in conductors for power and data, and with flexible lines for gases, liquids and vacuum. The flexible lines and patchboard will have self-sealing quick-disconnects and will be coded by size and geometry to preclude mismatch of contents.

If the space vehicle lacks capability for any of the utilities required by Life Sciences, this unit will include necessary supplementary sources. For example, several Life Sciences FPEs may require gases and/or liquids not available elsewhere, and it may be advantageous to provide a single source rather than several separate ones at the FPE or experiment level.

B.1.3.3 Performance Specification

a. Electrical Power: Input type and quality as provided by the space vehicle. Capacity 5 kW, minimum.

b. Pressurant Gas: Dry gaseous N_2 at 1 MN/m^2 gage (140 psig) and minimum flow capacity of 10 g/sec (80 lb/hr).

c. Purge Gas: Same as pressurant gas.

d. Heat Transport Fluid: Type and temperatures the same as space vehicle supply. Flow capacity 0.2 kg/sec (1600 lb/hr) at 100 kN/m^2 difference (14.5 psid).

e. Vacuum: Flow capacity 5 X 10^{-3} m^3/sec at 0.1 N/m^2 (10 cfm at 0.75 micron Hg).

B.1.3.4 Equipment Unit Summary

Power consumed, watts	200
Weight, kg (lb)	100 (220)
Volume, m^3 (ft^3)	0.5 (17.5)
Data rate, bps	10

B.1.4 PREPARATION, PRESERVATION AND RETRIEVAL UNIT

Some equipment representative of unit capabilities is illustrated in Figure 4.

B.1.4.1 Functional Capability. Detailed functional requirements are:

a. Specimen Autopsy

b. Sample Preparation

c. Sample Fixation

d. Histological Sectioning

e. Bacteriological and histological staining

f. Microbiological Sampling and Transfer

g. Organism Preservation

h. Specimen Preservation

i. Substrate Preparation: microbiology, histology, and invertebrate media

j. Sterilization: tools, cages, cage racks, instruments, biological preparation, biological wastes, food packages, and atmospheric gases

k. Cleaning and washing: tools, cages, holding systems, manifolding, laboratory ware and laboratory apparatus

l. Chemical storage and handling.

B.1.4.2 Description. This unit consists of two parts: a fixed work area with associated storage, and a laminar flow work bench which is transportable to any specimen holding unit or CORE equipment unit in the biology lab. Most of the equipment will be modules in racks adjacent to the fixed work area. Staining systems and specific chemical apparatus must have the functional side within the work area for safety.

The console or fixed work area will contain or be closely associated with the refrigerators, freezers, preparation centrifuge, lyophilyzer, cryostat, etc., as required for sample preparation and preservation. Consideration should be given to a manifold supply of high-use preservation fluids and sterilization gases from a general storage area. (Section B.1.3.)

The laminar flow bench (LFB) is a mobile workbench which is taken to the specimens or equipment unit. It is capable of being sealed to each unit and can be operated openly or with an airtight shroud containing a viewing window and gloves. This allows for experimentation with chemicals and biologicals which must not be exposed to the crew and its environment. By taking the workbench to the specimen, minimal environmental perturbation is experienced by the specimen during observations, measurements, and maintenance.

The laminar flow bench will be prepared from the main unit for specific operational tasks. Once loaded, the LFB is transported to the work site. In a similar fashion,

the LFB can be used as a transportation vehicle throughout the lab, receiving new supplies from docking ports, moving the supplies to stowage areas, and moving cages to wash and sterilization areas. When the workbench is removed, the crew seat and drive provide crew transport.

Two refrigerators and three freezers are required for this unit and are included in the volume. These units may be special cage racks compatible with the overall system or special refrigerator/freezers similar to off-the-shelf equipment.

Table 7 is an equipment list for the unit; Table 8 is an equipment unit summary.

B.1.5 BIOCHEMICAL/BIOPHYSICAL ANALYSIS UNIT. This unit is a central facility for accomplishing all biochemical and biophysical measurements not peculiar to the specimen holding units (Figure 3).

B.1.5.1 Functional Capability. Required capabilities of the Biochemical-Biophysical Analysis Unit are:

a. Major Atmospheric Gas Monitoring:

 1. At supply and exhaust.
 2. At specimen holding sites.
 3. Measurements: pO_2, pCO_2, pNH_3, pH_2O, pN_2, p (ethylene).
 4. Identification of other trace contaminants.

b. Biochemistry measurement:

 1. Creatine and Creatinine;
 2. Na, Ca, P, N, K, Cl, Mn
 Osmolality, Color, Sp. Gr., pH, Glucose, Bile, Blood and Microscopic Sulphates
 3. Electrolytes
 4. Total protein
 5. Protein Electrophoresis
 6. Bilirubin
 7. pH, pO_2, pCO_2
 8. Bicarbonate
 9. LDH and LDH Isoenzymes
 10. SGOT, SGPT
 11. Serum Free Thyroxin (T_4)

Table 7. Equipment List for Preparation, Preservation and Retrieval Unit

Name	Performance Characteristics	Power watts	Weight kg (lb)	Volume 10^{-3} m^3 (ft^3)	Remarks
High-Speed Centrifuge Refrigerated	Accommodates 50-ml tubes 0-18,000 rpm 0-40,000 g Temp. 253°K to 313°K	2000	90 (200)	510 (18)	May need counter-rotating design to null angular moment.
Micro Centrifuge	0.4-ml tubes 0-15,000 rpm	100	5 (10)	6 (0.2)	
Lyophilizer	Ambient to 113°K (-160°C)	0	5 (10)	23 (0.8)	Use space vacuum.
Microtome	Sections 1-50 μm	0	5 (10)	9 (0.3)	
Cryostat	78°K (-195°C)				
Freezer	193 to 233°K, 233 to 253°K, 253 to 273°K (-80 to -40°C, -40 to -20°C, -20 to 0°C)	300	36 (80)	425 (15)	Variable across exemplary ranges.
Refrigerator	277°K (4°C). Shielded chamber for radioisotope solutions.	100	18 (40)	283 (10)	
Vacuum Desiccator	TBD	0	5 (10)	57 (2)	Use space vacuum; combine with lyophilizer.
Veterinary Medical Kit	Includes otoscope/ ophthalmoscope, reflex hammer, hemoglobinometer, tourniquet, syringes, needles, scalpels, hemostats, tweezers, etc.	0	2 (5)	28 (1)	
Laminar Flow Bench	TBD	50	90 (200)	850 (30)	
Oven	TBD	1000	2 (5)	28 (1)	
Cryogenic System	To provide LN_2 for rapid cooling of biological specimens	0	45 (100)	43 (1.5)	
Toxic-Fluid Handling System	TBD	150	14 (30)	28 (1)	Part of laminar flow bench or fixed work station.

Table 7. Equipment List for Preparation, Preservation and Retrieval Unit, Contd

Name	Performance Characteristics	Power watts	Weight kg (lb)	Volume 10^{-3} m^3 (ft^3)	Remarks
Histology Kit/Slide Cabinet	Probes, knives, needles, syringes, cover slips, ladles, etc.	0	2 (5)	28 (1)	
Microbiology Kit	Transfer loops, syringes, pipettes, sensidiscs, biochemical test strips, cotton	0	2 (5)	28 (1)	
Induction Heat Tool Sterilizer	Flash heat, sterilize microbiological tools	500	0.5 (1)	3 (0.1)	
Automatic Plate Scanning Counter	Includes automatic sample changer and paper printout	20	9 (20)	28 (1)	
Bottles, Dishes, Test Tubes	TBD	0	5 (10)	85 (3)	
Media (dehydrated)	TBD	0	5 (10)	28 (1)	
Bacteriological Staining System	Perform 2 microbiological staining sequences.	50	7 (15)	43 (1.5)	Gram stain plus methylene blue.
Histological Staining System	Perform 3 histological staining sequences.	50	9 (20)	57 (2)	
Autoclave	2.07×10^5 to 2.75×10^5 N/m^2, 408°K (30-40 psia, 135°C.)	100	11 (25)	57 (2)	
Gas Sterilizer		100	9 (20)	103 (4)	
Sterilant Gas Management System		100	18 (40)	565 (20)	
Constant Temperature Block for Test Tubes and Vials	Ambient to 393 ± 0.5°K (120 ± 0.5°C)	100	2 (5)	7 (0.25)	

Table 7. Equipment List for Preparation, Preservation and Retrieval Unit, Contd

Name	Performance Characteristics	Power watts	Weight kg (lb)	Volume 10^{-3} m^3 (ft^3)	Remarks
Chemical Storage System	Ambient-temperature chemical storage. Connected to ECS for vapor control. Connected to space vacuum for emergency dump.	0	18 (40)	170 (6)	
Chemical Inventory	Inorganics. Organics. Biochemicals. Biologicals.	0	45 (100)	142 (5)	
Chemical Handling and Transfer Equipment	To allow transfer of liquids and granular solids from storage containers to reaction vials.	0	1 (2)	6 (0.2)	
Chemical Filtering Apparatus	Closed filtrations of gels and solids from liquids and gases.	0	2 (5)	14 (0.5)	
Shaker/ Mixer	Mixing of materials in bottles, test tubes and flasks.	30	5 (11)	14 (0.5)	

12. Hemotocrit
13. Hemoglobin
14. RBC Osmotic Fragility
15. RBC Mass and Survival
16. Bleeding Time
17. Clotting Time
18. Prothrombin Consumption
19. Clotting Retraction
20. WBC Mobilization - Rebuck method
21. Immunoglobins, Fibrinogen, Tranferins, Methonoglobin
22. Complement Titration
23. Antibody Titration
24. Plasma Volume

Table 8. Equipment Unit Summary

	Laboratory Only		Laboratory + Centrifuge	
OPERATOR SKILL	TBD		TBD	
POWER, AC				
average, watts	1200		1200	
peak, watts	TBD		TBD	
peak duration, hr/day	1		1	
POWER, DC				
average, watts	170		170	
peak, watts	TBD		TBD	
peak duration, hr/day	TBD		TBD	
WEIGHT, kg (lb)	500 (1100)		544 (1200)	
ENVELOPE	Basic	LFB	Basic	LFB
volume, m^3 (ft^3)	2.8 (100)	0.8 (30)	3.1 (110)	0.8 (30)
height, cm (in.)	TBD	150 (60)	TBD	150 (60)
width or diam, cm (in.)	TBD	90 (36)	TBD	90 (36)
depth, cm (in.)	TBD	40 (16)	TBD	40 (16)
DATA				
voice, hr/day				
TV, B&W, hr/day				
TV, color, hr/day				
analog, MHz	TBD		TBD	
digital, bps	1		1	

25. Ca, PO_4
26. Cholesterol
27. BUN
28. Uric Acid
29. Alkaline Phosphatase
30. Creatine Phosphokinase
31. ADH, ACTH
32. TBPA
33. 17-Hydroxy cortico steroids
34. Histamine
35. Lymphocyte Karotyping
36. RBC Enzyme Studies
37. Platelet Adhesiveness
38. Fibrinolytic Activity
39. Blood Rheology
40. Blood Lipids

c. Chemical Storage

d. Histochemistry: Stains

e. Metabolic Studies: Respiratory pO_2 and pCO_2. (If these measurements are accomplished at the holding site by specific ion electrodes, etc., the electrodes are experiment-specific supported by the Data Management Unit.)

f. Balance Studies:

1. Fluid, including sweat
2. Nitrogen, Minerals, Electrolytes
3. Accurate Urine Volume Measurement
4. Accurate Weight of Feces
5. Return of Total Dry Stool
6. Accurate Fluid Intake
7. Return of all food packages marked by date, time, and individual
8. Sweat sample return
9. Total Body Water - Breatholator or D_2

g. Physical Measurements:

1. Mass Measurements

(a) Macro – 0.1 to 30 kg ± 1 g

(b) Micro – 1 mg to 100 g ± 0.1 mg

2. Linear Measurements

(a) Rulers

(b) Micrometers

3. Polarography

4. Electrophoresis

5. General mass spectrometry

6. Spectrophotometry – UV, visible and IR

7. Gas chromatography of pyrolyzed solids, vaporized liquids, and gases.

h. Small Animal X-ray

B.1.5.2 Physical Description. This unit requires at least two functional areas: The atmospheric analysis area and the clinical biochemistry area. These functional areas are rack and module systems with associated work tables. The work tables may be required in the form of a laboratory hood system with the capability of glove-box operation by adding a gloved front enclosure. As such, the work area must be connected with appropriate atmospheric gas management systems to handle biological and chemical debris and solid and liquid spills. The mobile laminar flow bench system can be used for additional work space to support this equipment unit. Adjacent to the fixed workbench area and in the rack system must be the high-demand analytical instrumentation. Select instruments may even have sample injection ports within the gloved area.

The rack and module system should contain a high degree of standardization and commonality. Typically, the rack would accommodate three module sizes. Each size rack position would have common connections for electrical, pneumatic, and hydraulic supply inventory. The instrument modules could have connections only as required for that instrument. The connectors, having specific locations on the rack manifold and module, eliminate hookup error. Table 9 is an equipment list for the Biochemical/Biophysical Analysis Unit. Table 10 is an equipment unit summary.

Table 9. Equipment List for Biochemical/Biophysical Analysis Unit

Name	Performance Characteristics	Power watts	Weight kg (lb)	Volume $10^{-3}m^3$ (ft^3)	Remarks
Spectrophotometer IR	Range 2.5 to 12 μm Resolution 0.1% wavelength. Scan time 5 sec to 50 hr Sample temp RT to 423°K (250°C)	250	23 (50)	57 (2)	Heated flow through cell for use with gas chrommatograph.
Spectrophotometer	185 to 2000 mμm	10	2 (5)	28 (1)	
Automatic Physiological Gas Analyser	pO_2, pCO_2, and pH of blood	10	2 (5)	7 (0.25)	
Bench Chemistry Analysis Kit	TBD	10	18 (40)	103 (4)	Contains pipettes, solid chemical handling tools, vials, bottles, stoppers, safety devices and chemicals, rulers, micrometers, etc.
Automatic Urine Analyzer	TBD	50	9 (20)	28 (1)	
Work Bench	TBD	50	45 (100)	252 (9)	
Rack System for Modules	TBD	0	45 (100)	103 (4)	Volume is for rack space manifold, unusable area within rack.
Electroanalytical Apparatus	Current 0-100 mA. Scan Voltage 0-5V. Scan rate 0.5 mV/sec to 500 mV/sec.	10	9 (20)	28 (1)	
Electrophoresis Apparatus	Current 2 to 50 mA. Voltage 0 to 500 Vdc	20	9 (20)	28 (1)	Require Densitometer.
Gas Chromatograph	313°K to 673°K (40°C to 400°C) He carrier Hydrogen flame detector Thermal Conductivity Detector Fraction Collection System	100	5 (11)	17 (0.6)	Requires H_2, He and air or O_2 supply.
Macro Mass Measurement Device	0.1 kg to 30 kg ± 1 g	30	14 (30)	14 (0.5)	
Micro Mass Measurement Device	1 mg to 100 g ± 0.1 mg	15	5 (11)	14 (0.5)	

Table 9. Equipment List for Biochemical/Biophysical Analysis Unit, Contd

Name	Performance Characteristics	Power watts	Weight kg (lb)	Volume $10^{-3}m^3$ (ft^3)	Remarks
Mass Spectrometer	M/e 1-1000 Sensitivity to 1 ppm Unit resolution to 500 M/e	200	18 (40)	57 (2)	Use space vacuum. Couple with gas chromatograph. Need recorder.
Polarographic CO_2 and O2 sensors	pCO_2 1 to 20 mm Hg pO_2 0 to 1000 mm Hg	0	2 (5)	28 (1)	Require amplifier and readout. Weight and volume for 50 units each.
pH Meter	pH range 0 to 14 Accuracy ±0.001 Compatible with zero-g chemical vials	12	5 (11)	14 (0.5)	Accessories: Various electrodes. Standardization solutions. Zero-g sample vials.
Automatic Atmospheric Trace-Gas Monitoring Unit	Measure select groups of aromatic and aliphatic hydrocarbons and inorganic gas contaminants	500	45 (100)	510 (18)	Must be capable of commutating automatically over a number of sample ducts.
Blood Gas Analyzer	Measure pO_2, pCO_2 and pH in whole anticoagulated blood.	40	2 (5)	11 (0.4)	

Table 10. Equipment Unit Summary

	Laboratory Only	Laboratory + Centrifuge
OPERATOR SKILL	TBD	
POWER, AC		
average, watts	100	100
peak, watts	100	100
peak duration, hr/day	16	16
POWER, DC		
average, watts	1300	1300
peak, watts	1300	1300
peak duration, hr/day	16	16

Table 10. Equipment Unit Summary, Contd

	Laboratory Only	Laboratory + Centrifuge
WEIGHT, kg (lb)	258 (570)	258 (570)
ENVELOPE		
volume, m^3 (ft^3)	17 (60)	17 (60)
height, cm (in.)	150 (60)	150 (60)
width or diam, cm (in.)	240 (96)	240 (96)
depth, cm (in.)	60 (24)	60 (24)
DATA		
voice, hr/day	TBD	TBD
TV, B&W, hr/day	TBD	TBD
TV, color, hr/day	TBD	TBD
analog, MHz	TBD	TBD
digital, bps	1	1

B.1.6 MAINTENANCE, REPAIR AND FABRICATION. The Maintenance, Repair, and Fabrication Unit is for instrument cleaning, repair and checkout, apparatus maintenance, modification and fabrication, and cage cleaning.

B.1.6.1 Functional Capability. Functional requirements are:

a. Instrument Checkout

b. Instrument Repair

c. Instrument Modification

d. Hardware Fabrication

e. Apparatus and Instrument Cleaning

f. Cage Cleaning

g. Pneumatic and Hydraulic Manifold Maintenance

h. Electrical Harness Modification and Repair

i. Equipment Maintenance (Filter replacement, battery replacement, etc.).

B.1.6.2 Description. This is a work bench with associated rack and modules for checkout, repair and fabrication. A second work bench is the general cleaning area containing the cage washer, drying oven, ultrasonic cleaner, and instrument and apparatus cleaning system.

Table 11 lists equipment for the unit, and Table 12 is an equipment unit summary.

B.1.7 ANCILLARY STORAGE

B.1.7.1 Functional Capability. This equipment unit will provide general storage area and specific storage for instruments and hardware required.

B.1.7.2 Description. This will consist of either open areas or cabinets with appropriate tie-downs for miscellaneous hardware. Typical items to be stored are of the following sizes: 25 × 25 × 100 cm (10 × 10 × 40 in), 75 × 75 × 100 cm (30 × 30 × 40 in), and 150 × 150 × 100 cm (60 × 60 × 40 in); analytical instruments of various sizes up to 0.56m^3 (2 ft^3); disposable instruments in packages up to 0.56m^3 (2 ft^3); boxes of vials, dishes and apparatus up to 0.56m^3 (2 ft^3), etc.

Table 13 lists equipment for the ancillary storage; specific envelope dimensions are to be determined later.

B.2 SPECIMEN RETURN UNIT

This unit and the units described in the following sections are not part of the CORE.

The requirements for a Specimen Return Unit and its frequency of operation will depend upon the following factors:

a. Frequency of Shuttle visits to the Space Station.

b. On-board sample analysis or examination capability.

c. Predictability of sample degradation with time.

Preliminary studies have demonstrated the feasibility of utilizing a modified Discoverer type capsule, such as the recoverable Biosatellite spacecraft, if a Specified Return Unit is required.

B.3 BIOLOGICAL RESEARCH CENTRIFUGE

The requirement for the capability to provide accelerative force in space is based upon the fact that long-term fractional g is no more attainable by any other technique than is the achievement of long-term weightlessness without orbital flight. The functions to be performed by this capability include:

a. In-flight 1-g controls.

b. Controlled, graded levels of acceleration to establish thresholds of response to acceleration.

Table 11. Equipment List for Maintenance, Repair and Fabrication Unit

Name	Performance Characteristics	Power watts	Weight kg (lb)	Volume 10^{-3} m^3 (ft^3)	Other or Remarks
Drying Oven	Ambient to 398°K (125°C)	600	18 (40)	57 (2)	
Ultrasonic Cleaner	20 kHz with piezoelectric transducers	30	9 (20)	28 (1)	
General Tool Kit	Wrenches, hammer, pliers, screwdrivers, drills, saws, punches, files, vise, etc.	50	9 (20)	28 (1)	
Micro Tool Kit	Same as general tool kit except precision micro tools	50	5 (11)	14 (0.5)	
Oscilloscope	DC to 5 MHz	100	1 (2)	28 (1)	
Volt Ohmmeter		0	1 (3)	3 (0.1)	
Electronic Tools	Terminal crimpers, wire strippers, screwdriver, pliers	0	5 (11)	14 (0.5)	
Electronic Hardware	Terminals, wire replacement plugs and receptacles	0	14 (31)	14 (0.5)	
Cage Washer	Specimen cage cleaner	500	90 (200)	283 (10)	
Signal Generator	0.01 to 20,000 Hz	50	2 (5)	14 (0.5)	
Instrument and Apparatus Washer		500	45 (100)	140 (5)	

Table 12. Equipment Unit Summary

	Laboratory Only	Laboratory + Centrifuge
OPERATOR SKILL	TBD	
POWER, AC		
average, watts	1880	
peak, watts	1880	
peak duration, hr/day	16	
POWER, DC		
average, watts	100	
peak, watts	100	
peak duration, hr/day	16	
WEIGHT, kg (lb)	200 (440)	
ENVELOPE		
volume, m^3 (ft^3)	1.7 (60)	
height, cm (in.)	TBD	
width or diam, cm (in.)	TBD	
depth, cm (in.)	TBD	
DATA		
voice, hr/day	TBD	
TV, B&W, hr/day		
TV, color, hr/day		
analog, MHz	TBD	
digital, bps	0	

Table 13. Equipment List for Ancillary Storage

Name	Performance Characteristics	Power watts	Weight kg (lb)	Volume m^3 (ft^3)
Various shelves and cabinets	Equipment Storage	0	45 (100)	2.8 (100)

c. Determination of the degree and reversibility of deconditioning or, conversely, determination of the rate of re-adaptation of organisms to acceleration.

In centrifuge work, particularly with animals, the coriolis effect is of concern. In both plant and animal centrifuge work, it is necessary to have a minimum of interruption in rotation. Optimally, the investigator is able to tend experimental subjects on the centrifuge without interruption of rotation. Since the magnitude of coriolis forces is directly proportional to angular velocity (ω) and indirectly proportional to the radius arm (r), the ideal centrifuge would have characteristics such that $r \rightarrow \infty$, $\omega \rightarrow 0$, and $kr\omega^2 \rightarrow g$.

The centrifuge could thus have from a minimum diameter of 17.7m (58 ft.) to a maximum diameter of 17.7n meters (58n feet) by coupling 17.7-m (58 ft) units end to end or by employing radially telescoping units about the axis of rotation.

B.3.1 DESCRIPTION. A centrifuge facility of the greatest feasible radius is required to minimize coriolis phenomena. The centrifuge must be capable of providing 2g at the specimen area. A concept is illustrated in Figure 5. The following specification should be considered:

a. Load: 44 cage racks.

b. Subsystems for Experiments: 1 Laminar Flow Bench (LFB) from Main Lab.

c. Access: 114 cm (45 in) hatch and tunnel.

d. Main Accommodation: Chair translocator.

e. Experiment Support: Identical to Main Lab.

f. Balance: Dynamic balance of man plus 1 cage-rack removal.

g. Operation Time: 90 days continuous (up to 300 days).

h. Work Table: 60 cm x 90 cm (24 in x 36 in).

i. Man Rated: Dynamic

Table 14 lists Biological Research Centrifuge equipment. Table 15 is the equipment unit summary. The centrifuge is envisioned as a separate module 4.26m (14 ft) in diameter by 17.7m (58 ft) long providing a 8.8m (29 ft) radius system. It would be

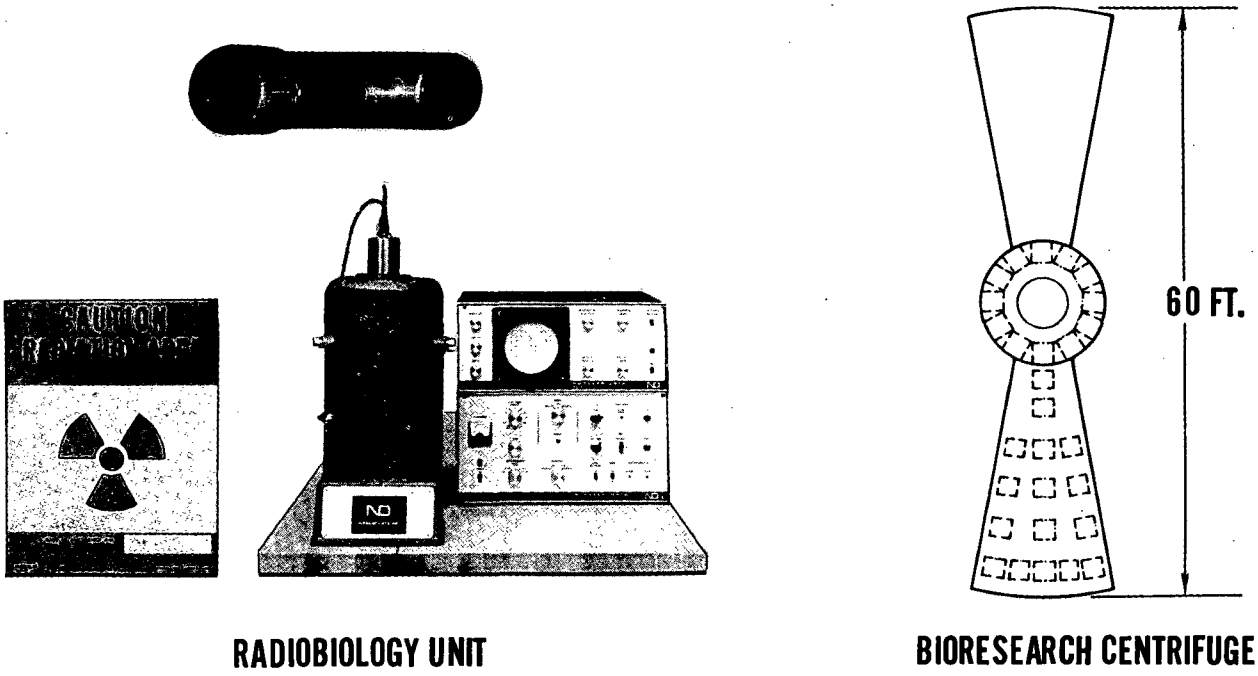


Figure 5. Vertebrate Research Facility

Table 14. Biological Research Centrifuge Equipment List

Name	Performance Characteristics	Power watts	Weight kg (lb)	Volume m^3 (ft^3)
Centrifuge Facility	Up to 2g; maximum feasible radius.	4000	6350 (14,000)	250 (8900)
Laminar Flow Bench	Atmospheric isolation - man to specimens. Clean, adequate work area.	100	180 (400)	0.8 (28)
Work Table	61 cm x 91.5 cm (24 x 36 in.) top with various tiedowns.	0	9 (20)	0.3 (10)
Man Translocator	Transport man alone or man plus Laminar Flow Bench throughout the centrifuge.	250	45 (100)	0.3 (10)

Table 15. Equipment Unit Summary

	Laboratory Only	Laboratory + Centrifuge	
OPERATOR SKILL		TBD	
POWER, AC			
average, watts		4000	
peak, watts		5000	
peak duration, hr/day		1	
POWER, DC			
average, watts		TBD	
peak, watts		TBD	
peak duration, hr/day		TBD	
WEIGHT, kg (lb)		6350 (14,000)	
ENVELOPE		Stored	OPS
volume, m^3 (ft^3)		250 (8900)	TBD
height, m (ft)		17.7 (58)	TBD
width or diam, m (ft)		4.26 (14)	TBD
depth, m (ft)		TBD	TBD
DATA			
voice, hr/day		TBD	
TV, B&W, hr/day		TBD	
TV, color, hr/day		TBD	
analog, MHz		TBD	
digital, bps		TBD	

launched separately and docked to the main lab. No preliminary engineering has been performed. The values shown in Table 15 are approximately 1-1/2 times the values for a smaller 6.7-m (22-ft) diameter system except that power was doubled for the increased momentum.

B.4 RADIOBIOLOGY UNIT

B.4.1 FUNCTIONAL CAPABILITY. The Radiobiology Unit (Figure 5) will provide facilities for (1) irradiating biological specimens (vertebrates, invertebrates, plants, cells and tissues) to determine the effects of ionizing radiation on the various biological systems in the weightless state (e.g., the interaction of radiation and weightlessness on the radiation-induced injury process, recovery, chromosomal aberrations, somatic and genetic mutations, performance and behavior, etc.); (2) diagnostic procedures of onboard personnel; and (3) radioisotope tracer study capability.

B.4.2 DESCRIPTION. Radiobiology Unit facility requirements are as follows:

a. Radiation Exposure Room with entry door for conducting the irradiation and for housing the shielded gamma-radiation source. Minimum dimensions of the circular room are 2.5m (8.1 ft) in diameter and 2.5m (8.1 ft) high. The door, ceiling, floor, and walls are to be properly shielded with sufficient thickness of lead sheeting to attenuate the penetrating radiation during exposure (with the onboard source) to levels consistent with the Radiation Safety Code for personnel (i.e., radiation workers). An appropriate lead-impregnated window must be located at standing eye level, either on the door or in the wall (preferable) adjacent to the control panel. The onboard radiation hazard can be effectively minimized by locating the room in an uninhabited, remote peripheral area of the spacecraft and by directing the radiation from the source outward from the spacecraft. The dimensions of the exposure room will permit simultaneous exposure of several to many specimens. Furthermore, uniform exposures of all specimens can be achieved by taking into account the contour of the effective exposure field and arranging the specimens accordingly, and the exposure dose rates can be varied considerably to fulfill the needs of the investigators by positioning the specimens at varying distances from the source. The room must be provided with appropriate controls for lighting, ventilation, temperature, pressure, humidity, etc.

b. Gamma Isotope Radiation Source (e.g., 2-3 curies of Co^{60} or Cs^{137}) encased in sufficient shielding material (lead) to meet the personnel Radiation Safety Code requirements while in storage. The source, located about one meter (3 ft) above the floor in the Radiation Exposure Room, either in the wall or adjacent to the wall, will be activated by remote control from a panel located either outside the Exposure Room (preferable) or in the CORE. The control panel will contain an automatic timing device for setting the exposure time, and direct readout capabilities for the radiation monitoring system which will indicate the dose rate and total dose delivered and will be designed to differentiate the ambient radiation from that of the onboard source. Readout data will be documented, stored, and

returned to ground for analysis. The timer will be set by the operator and automatically activated at the start of exposure, and will automatically inactivate the radiation source upon completion of the exposure.

c. Radioisotope Storage Unit, used to store radioisotopes. It will consist of two containers about 25 × 25 × 20 cm (10 × 10 × 8 in). All surfaces will be lined with lead of appropriate thickness (about 0.5 to 1.0 cm) to satisfy requirements of the Radiological Safety Code for radiation workers. One container will be kept in a refrigerator and the second will be at room temperature.

d. Radiobiology Laboratory, used for injecting radioisotopes and counting radioactivity in tissue, blood, fecal and urine samples obtained from radioisotope-injected specimens or whole specimens. The room, approximately 3m (10 ft) wide, 3m (10 ft) long, and 2.5m (8 ft) high, must be provided with all utilities (vacuum, lights and a minimum of 12 electrical outlets, gas, and hot and cold water); temperature, humidity, pressure, and ventilation controls; counter tops, cabinets and drawers, etc. A radioisotope hood, about 1.5m (5 ft) long, 1m (3 ft) deep, 1.3m (4 ft) high, with appropriate filters and enclosed like a glove box, will be needed for injecting radioisotopes, withdrawing blood, dissecting specimens, etc. The hood must be provided with all utilities, at least four electrical outlets, lights, etc. Appropriate instruments (surgical, suturing needles, syringes, hypodermic needles, etc.) must be provided. A sterilizer unit will be necessary. Management and control of readout data from the radioisotope counting equipment will either be coupled to the CORE or provided in the laboratory. Data must be analyzed, documented, and stored for return to ground. The laboratory floor, counter tops, etc. must be provided with appropriate surfaces for radioisotope use. A radioactive material waste disposal must be provided.

e. Diagnostic X-ray Unit and Facility, used for bone densitometry, accidents, crystalography, structural stress in metal, chemical analysis and identification, medical application (e.g., lungs, bones, stones, teeth), etc. The facility will consist of a room about 2.5m (8 ft) wide, 3m (10 ft) long, and 2.5m (8 ft) high. Walls, ceiling, floor, and door must be properly lead-lined to comply with the Radiological Safety Code for personnel outside the room. Adequate controls must be provided on the outside (or in the CORE) for lighting, ventilation, temperature, humidity, pressures, etc. Electrical outlets (minimum of four) must be provided inside the room.

 The X-ray Unit will be an appropriate low voltage (e.g., 50 kVp) diagnostic machine with the capability of exposing downward as well as laterally. Controls for operating the unit will be located outside the room (preferable) or in the CORE. An appropriate lead-impregnated window must be located either in the door or in the wall (preferable) at standing eye level, either above or adjacent (preferable) to the control panel.

B.4.3 EQUIPMENT/LABORATORY/CREW INTERFACE

B.4.3.1 Gamma-Emitting Radioisotope Exposure Source. The source (2-3 curies) is encased in a sufficiently lead-shielded source holder which is activated open by command of onboard personnel, and closed automatically upon termination of exposure.

a. Envelope: To be determined

b. Weight: about 50 kg (110 lb) for source; weight for shielding of room to be determined.

c. Power: 50 watts continuous, with peak of 75 watts when opening or closing source holder.

d. Data: Minimum visual readout and recording by crew.

e. Crew Interaction: Take dosimetry, set up specimens for exposure, set timer, activate source, and record exposure data (e.g., exposure time, dose rate, total dose, etc.).

f. Thermal: 50 watts continuous.

g. Special: Circulating air to be provided by laboratory ECS. Warning lights required to indicate open source holder. Door to remain locked while source holder is open. Shielding of exposure room to comply with Radiological Safety Code for radiation workers.

h. Estimated Development Time: 2-3 years.

B.4.3.2 Dosimeters. Both active (e.g., Victoreen) and passive (e.g., film or lithium fluoride), must be provided. The active dosimeters will monitor the exposure dose and dose rate with the data readout instrument located outside the room on the panel (or in the CORE). Passive as well as active audible dosimeters will be worn by the operator and onboard personnel. Passive dosimeter readout and recording capability must be provided. For the lithium fluoride dosimeters, a small heating unit (e.g., furnace) will be required.

A means of determining the source-to-specimen distances must be provided. This could be predetermined and/or a measuring device (e.g., tape or meter stick) provided.

Specimen exposure units for irradiating vertebrates, invertebrates, plants, cells and tissues will be required.

B.4.3.3 Radioisotope Counting Equipment. Both gamma and beta counting equipment and survey meters will be required.

a. Envelope: TBD

b. Weight: TBD

c. Power: TBD

d. Data: Management and readout capability in the CORE; to be dumped once daily.

e. Crew Interaction: Inject isotopes, withdraw blood, dissect tissue, etc., prepare samples for counting, put into counter and activate counter, remove samples from counter, either store samples in freezer for return to ground or discard, depending on experiment protocol.

f. Thermal: None required.

g. Special: Radiological Safety Code and Procedures to be observed by onboard investigators. Provisions for cleaning radioisotope contamination (e.g., spillage, etc.) must be provided.

h. Estimated Development Time: 2-3 years.

B.4.3.4 X-ray Equipment (Diagnostic). Requirements are:

a. Envelope: 60 cm (24 in.) × 45 cm (18 in.) × 30 cm (12 in.).

b. Weight: 25 kg (55 lb) X-ray Unit; shielding of X-ray room walls, door, ceiling and floor to be determined.

c. Power: 1500 watts for 10 seconds.

d. Data: Require scanning densitometer to send data back to Earth. (A radioisotope photon absorption method rather than the X-ray bone densitometry method may be used.)

e. Crew Interaction: Take dosimetry, set up the material or subject for exposure, set exposure timer, activate exposure, record exposure data (e.g., exposure time, dose rate, total dose), etc.

f. Thermal: Water cooling not required; warm up not required.

g. Special: X-ray film development facility; operator and onboard personnel shielding to comply with Radiological Safety Code for radiation workers (i.e., limited to 40 mrad/week and no single dose over 5 mr).

h. Estimated Development Time: 2-3 years.

B.5 AIRLOCK/EVA CAPABILITY UNIT

B.5.1 FUNCTIONAL CAPABILITY. This equipment unit provides the crew with the capability for extravehicular activities (EVA). The following functions can be performed with the equipment items forming this unit:

a. Passage from within the vehicle to the space environment without disturbing the vehicle environment.

b. Life support while in the EV environment.

c. Protection from drifting free of the spacecraft.

d. Illumination as required.

e. Crew monitoring as required.

B.5.2 DESCRIPTION. This unit involves a diverse group of equipment items in terms of weight, volume, function, portability, etc. Nevertheless, each is required as a component of the unit to ensure that the crew's EVA sojourn is safe and effective.

a. The airlock is the hardware that will allow controlled passage from the IVA to the EVA environment and vice versa. The airlock could vary considerably in terms of weight, volume, power, and even portability, depending on its functional requirements, anticipated frequency of use, capacity requirements, etc. As a minimum, it could be a lightweight, 150-cm (60-in) diameter, one-man, "elastic recovery," expandable airlock similar to the Air Force "Experiment D021" airlock. This provides a portable system, fulfilling the airlock function, that is just large enough for one pressure-suited man to maneuver in satisfactorily. See Figure 6.

 Since the airlock could encompass larger systems such as the Skylab airlock module on up to large, high-capacity units designed for retrieval of large pieces of hardware, the minimum provisions, identified as such, will be included as a starting point in this document's weight, volume, etc., summaries.

b. Life support will be provided by a space suit and umbilical or PLSS. These are portable items similar to the Apollo A-7L-B system.

c. A safety tether and control unit will be used to prevent loss of contact with the spacecraft. Estimated maximum length is 30.5 meters (100 feet).

d. Illumination in the form of portable or permanently installed lighting fixtures will be used when night or shadow operations are required. Reflectors will be used when advantageous, such as on handrails, etc.

e. Crew monitoring will consist of voice communications, viewing ports, biomedical instrumentation, etc.

Table 16 is the Airlock/EVA Capability Unit equipment list. The equipment unit has the following characteristics:

a. Weight: 217 kg (479 lb), minimum

b. Volume: 2.5m^3 (88 ft^3)

c. Power Requirements: Average, 513 watts
 Peak, 700 watts
 Peak Duration, 2 hours/day.

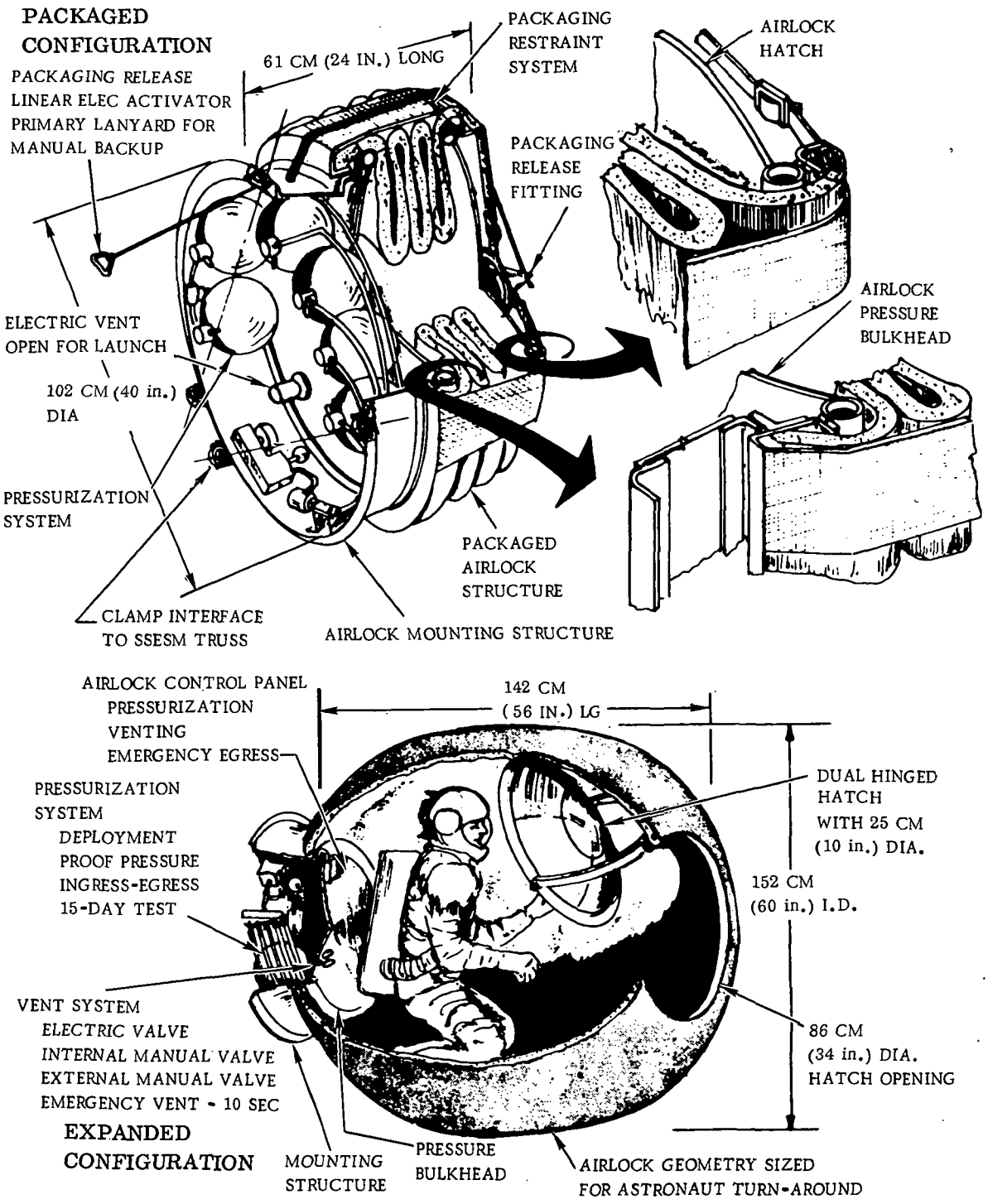


Figure 6. D021 Hardware

Table 16. Equipment List for Airlock/EVA Capability Unit

Name	Features	Weight kg (lb)	Volume m^3 (ft^3)	Power watts	Envelope (Operational)
Airlock	Portable, expandable, controlled-environment chamber (minimum).	45 (100)	1.8 (63)	10	Spherical; 1.52m (5 ft) dia.
Space Suit & PLSS	Cooling garment, inner liner, ventilation system, pressure bladder, ITMG, back pack.	74 (164)	0.23 (8)	Self-contained	1.83 × 0.71 ×0.508m (72 × 28 × 20 in.)
Safety Tether & Control Unit	Flexible, nonkinking line.	7 (15)	0.03 (1)	3	30.5m (100 ft) length
Illumination	Portable and/or permanent installation.	4.5 (10)	0.03 (1)	200	
Crew Monitoring	Communications, viewing ports, biomedical instrumentation.	90 (200)	0.43 (15)	300	

VOLUME VIII

SECTION 1

MEDICAL RESEARCH FACILITY

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MEDICAL RESEARCH FACILITY

1.1 GOALS AND OBJECTIVES

Medical experiments will be devoted to the evaluation of changes in human function and capabilities which may be induced by very long duration space flight which will afford the opportunity to (1) explore in greater detail the functional alternatives already encountered in our manned space flight experience, and (2) accomplish the in-depth monitoring required to ascertain physiological effects which have not so far become evident.

The overall objectives of the Medical experiments program are:

a. To extend man's capabilities in manned space flight by determining:
 1. The effects of space flight on man, and the time course of these effects.
 2. The specific mechanisms by which these effects are mediated.
 3. Means of predicting the onset and severity of undesirable effects.
 4. The most effective means of prevention or correction of undesirable effects.

b. To obtain scientific information of value to conventional medical research and practice.

c. To obtain specific information on the combined effects of stress and zero-g using animal subjects.

The objectives will be obtained by means of individual measurements to explore each of several areas of body function toward which the medical experiments program effort has been directed. These areas of study include neurological function, cardiovascular function, renal function, nutrition and metabolic function, musculoskeletal function, pulmonary function, hematologic function, microbiology and immunologic function, endocrine function, clinical/therapeutic function, and environmental factors.

In pursuing these objectives, basic principles apply which relate clearly to flight program planning.

a. The key variable in the evaluation of man in space is duration of flight.

b. It is important to obtain as great a redundancy of pertinent measurements in individual crew members as is practicable in any given flight configuration to establish statistical validity.

c. A major practical aim of this effort is to use these observations in the preparation of appropriate preventive or remedial techniques such as lower body negative pressure, special exercises, and other conditioning methods for maintaining man in a satisfactory condition during future long-duration missions. This will include the evaluation of the long-term effects of zero-g to determine the desirability or need for artificial gravity, i.e., to conduct the observations required in order to make the so-called "g decision."

1.2 PHYSICAL DESCRIPTION

The laboratory system to accommodate the medical experiments will consist of modular equipment units which can be arranged according to the requirements of the spacecraft and the medical experiments program. The Medical Research Facility will draw heavily upon the Life Sciences CORE plus other supportive equipment units (Figure 1-1).

1.2.1 BIOMEDICAL MEASUREMENTS UNIT. This unit provides the instrumentation needed to interface the human subject with the medical experiments for those measurements which are not included in the Life Sciences CORE facility. In general, the instrumentation in this unit services more than one experiment and falls into one of the following areas:

a. Transducers and preamplifiers -- those devices that interface with the subject directly, sensing electrical signals, rates, and flows (e.g., ECG, EMG, pulmonary flowmeter).

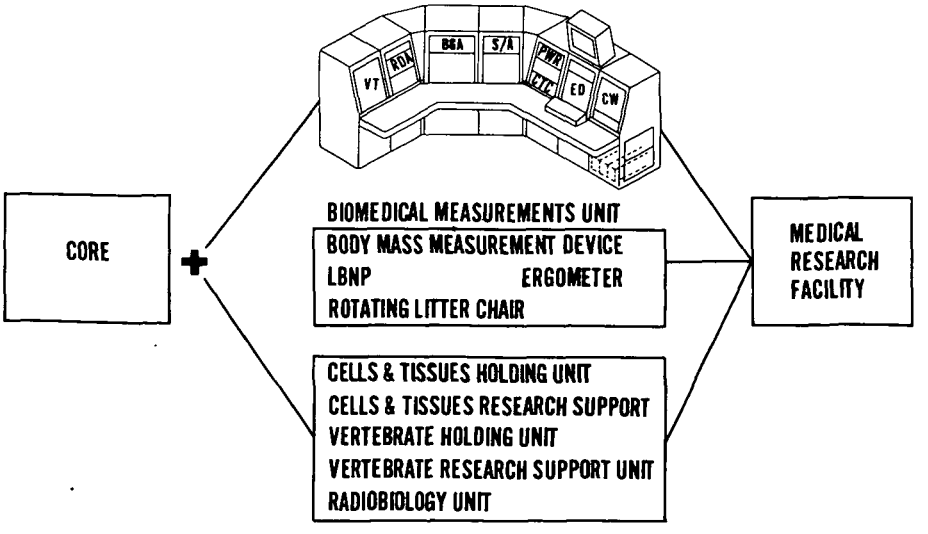


Figure 1-1. Medical Research Facility

b. Peripheral devices -- major support equipment for conducting certain experiments (e.g., LBNP, litter chair).

All of this instrumentation forms the Biomedical Measurements Unit and supports medical research in the areas of neurology, cardiovascular physiology, and respiration and metabolism. Additional support equipment in the areas of blood and urine analysis, microbiology, histology, and bioassays, along with data management and medical research facilities for animals, are found in the CORE or various other equipment units under the Life Sciences FPE's.

1.2.1.1 Functional Capability. The Biomedical Measurements Unit provides for the following measurements.

Functional Area	Measurement
I. Neurology	Agravic Perception of Personal and Extra-personal Space
	Ocular Counter-rolling
	Oculogyral Illusion
	Visual Task with Head Rotation
	Electronystagmogram (ENG)
	Angular Acceleration Threshold
	Coriolis (Motion) Sickness Susceptibility
II. Cardiovascular Physiology	Phonocardiogram
	Cardiac Output Impedance Method
	Regional Blood Flow (Limb or Digit)
	Venous Compliance
	Arteriole Reactivity
	Arterial Pulse Contour
	Inflight Exercise - Ergometer
	LBNP
	Elastic Leotards
III. Respiration and Metabolism	Respiration Rate
	Lung Volume, Including Residual Volume
	Pressure, Flow and Volume - Airway Resistance
	Compliance (Lung or Total)
	Distribution of Blood Flow in Lungs
	Lung Capillary O_2, CO_2 and pH
	Breath-by-Breath O_2 Consumption and CO_2 Production

Functional Area	Measurement
III. Respiration and Metabolism, Contd	O_2 Consumption - with Measured Exercise
	Alveolar to Arterial Gradient (Breathing Air and 100% O_2)
	Caloric Intake
	Body Mass In-Flight - Thornton Technique
	Muscle Size and Strength
	Specimen Mass Measurement Device

1.2.1.2 Description. The Biomedical Measurements Unit consists of a console capable of accepting plug-in modules for the various measurement functions required. Transducers and associated leads and cables are stored in console drawers along with disposable supplies (e.g., syringes, tape, etc.). Cabling is provided to connect the peripheral devices, which are not part of the main console, to the console and also to interface this equipment unit and others, specifically the Data Management Unit and the Biochemical/Biophysical Analysis Unit of the CORE. A work area is provided on the console for manual data logging and as a small work bench. Table 1-1 lists Biomedical Measurements Unit equipment.

1.2.1.3 Equipment Unit Specification Summary. The following is a summary of the equipment unit specification:

Weight: 300 kg (660 lb)
10-15 kg (22-33 lb) per resupply

Volume: 2 m^3 (70 ft^3), including peripherals' volumes

Power: Average - 280 watts
Peak - 450 watts
Peak Duration - 2 hr/day
Standby - 35 watts

Data: Digital - 2 kbs, 1 hr average/day
Material - 10 kg/mo (20 lb/mo), samples, logs, records, etc.

Other: Nominal zero-g required, i.e., 10^{-4} g, during mass measurements and use of rotating litter chair.
Environmental temp. - 295±3°K (72±5°F).
Initial logistics - medical supplies, logs, etc. - 15 kg (30 lb)

Table 1-1. Equipment List

Name	Performance Characteristics	Available Model	Pwr (W)	Wt kg (lb)	Vol m^3 (ft^3)	Other or Remarks
Impedance Cardiograph	2-25 liters/min ± 5% full-scale (cardiac output)		5	2.2 (5)	0.007 (0.2)	Measures thoracic impedance change which is related to cardiac output.
ECG/VCG (leads and preamp)	0-3 mV ± 1% f.s.	Skylab M093	1	1.8 (4)	0.01 (0.3)	Needs recording of up to 12 heart waveform channels.
EEG (leads and preamp)	10-200 μV ± 1% f.s. 0.2-100 Hz Up to 6 channels	Skylab M133	1	0.5 (1)	0.001 (0.05)	Needs Oscillographic Display.
Dynamometers	Arm flexion: 10-35 kg (25-75 lb) Back extension: 40-80 kg (100-200 lb)	Under development	None	1.8 (4)	0.03 (1)	Manual data entry.
EMG (leads and preamp)	Both invasive and non-invasive electrodes. 0.01-5 mV ± 1% f.s. Selectable BWs: 0.5-200 Hz 0.5-1000 Hz 1 channel	Under development	1	0.9 (2)	0.003 (0.1)	Needs data display.
EOG (lead and preamp)	0.1-1 mV ± 1% f.s. 0.14-100 Hz (2 channels)	Skylab M133	1	0.5 (1)	0.001 (0.05)	Needs data display.
Phonocardiogram (microphone and preamp)	0.1-1000 Hz ± 5% f.s.	NASA-MSC for Gemini Spacelabs for Apollo	1	0.5 (1)	0.001 (0.05)	Needs Oscillographic Display.
Leg Plethysmographs	Strain gauge technique ± 10% local reading (cross-sectional area)	Skylab M092	5	2.2 (5)	0.007 (0.2)	Measures leg circumference to deduce blood volume and flow.
Metabolic Analyzer	Flowmeter and mass spectrometer Volumes of O_2 and CO_2: 0-40 l/min ± 3% f.s. Alveolar pO_2: 20-120 mm Hg ± 2% f.s.	Skylab M171	30	18 (40)	0.1 (3)	Measures O_2 consumption, CO_2 production, maximal O_2 consumption and alveolar pO_2 and pCO_2.

Table 1-1. Equipment List, Contd

Name	Performance Characteristics	Available Model	Pwr (W)	Wt kg (lb)	Vol m^3 (ft^3)	Other or Remarks
	Alveolar pCO_2: 20 - 70 mm Hg ± 2% f.s. Displays: consumption rates, RQ and pressures					
Pulmonary Flowmeter	Volumes: 0-7 l ± 3% Flow rates: 0-15 l/min ± 3% Displays: volume and flow rate	Donti Flowmeter	1	0.5 (1)	0.003 (0.1)	Needs recording of volume and flow rate.
Tape Measure	0-125 cm ± 0.10 cm (0-50 in. ± 0.05 in.)	Standard Item	None	0.1 (0.2)	0.0003 (0.01)	Manual data entry.
Transcutaneous Doppler Flowmeter	Ultrasonic signal 1 and 5 MHz	Ward System by A.L. Wolff Co.	5	2.2 (5)	0.006 (0.2)	Measure pulse wave contour. Need recording.
Pulse Wave	3-15 m/s ± 0.1 m/s Display: velocity	Under development	2	0.9 (2)	0.003 (0.1)	Used with ECG/VCG + Transcutaneous Doppler Flowmeter. Needs recording of velocity.
PERIPHERALS						
Bicycle Ergometer	0-300 watts ± 2% f.s. Folding model Controlled and calibrated work load	Skylab M171	10	22 (50)	0.1 (4)	Operating volume of 0.3 m^3 (10 ft^3) includes subject. Needs recording of work load.
Rotating Litter Chair	Folding chair, motor base & control console with displays	Skylab M131	210	90 (200)	0.6 (20)	Operating volume of 1 m^3 (30 ft^3) includes subject. Needs recording of chair RPM.
LBNP	50 mm Hg below cabin ambient, ± 0.5 mm Hg Display - internal pressure differential	Skylab M072	10	70 (155)	1 (35)	Operating volume of 1.2 m^3 (40 ft^3).

Table 1-1. Equipment List, Contd

Name	Performance Characteristics	Available Model	Pwr (W)	Wt kg (lb)	Vol m^3 (ft^3)	Other or Remarks
Specimen Mass Measurement Device	Mass pan supported on two plate fulcra springs (mass determined by osc. frequency) 0.05-0.5 kg (0.1-1 lb), ± 0.1% local reading Display: mass	Skylab M074	2	5 (11)	0.01 (0.3)	Includes calibration weights. Needs recording of mass.
Body Mass Measurement Device	Spring/flexure pivot-mounted (mass determined by osc. frequency) 50-100 kg (125-230 lb) ± 0.1% local reading) Display: mass	Skylab M172	2	18 (40)	0.25 (9)	Operating volume 0.7 m^3 (20 ft^3) includes subject. Needs recording of mass.

1.2.2 OTHER EQUIPMENT. The Medical Research Facility requires additional equipment which is shared with other FPEs. These equipment units are:

Equipment Unit	Location	Reference Section
Visual Records and Microscopy Unit	CORE	B.1.1
Data Management Unit	CORE	B.1.2
Life Sciences Experiment Support Unit	CORE	B.1.3
Preparation, Preservation and Retrieval Unit	CORE	B.1.4
Biochemical/Biophysical Analysis Unit	CORE	B.1.5
Maintenance, Repair and Fabrication Unit	CORE	B.1.6
Ancillary Storage	CORE	B.1.7
Small Mammal Holding Unit	FPE 2	2.2.3
Vertebrate Research Support Unit	FPE 2	2.2.1
Cells & Tissues Holding Unit	FPE 4	4.2.1
Cells & Tissues Research Support Unit	FPE 4	4.2.2
Radiobiology Unit	CORE Growth	B.3

1.3 EXPERIMENT REQUIREMENTS SUMMARY

The weights, volumes, and power listed for each experiment in Table 1-2 include all the requirements necessary to perform the experiment, regardless of whether the equipment is experiment-peculiar or is located in the CORE.

1.4 EXPERIMENT PROGRAM

The medical research program is comprised of a group of representative experiment classes, each supported by a group of representative experiments. Within each class, the first of the representative experiments is described in detail; the other representative experiments are given by title only. These selected representative experiments provide experiment support requirements and other spacecraft and mission impacts to a level that is ample to characterize the requisite Medical Research Facility. Table 1-3 ennumerates the representative experiment classes and representative experiments which scope the experiment program.

Table 1-2. Experiment Requirements Summary

EXPERIMENT	MASS (WEIGHT) kg	(lb)	VOLUME m^3	(ft^3)	POWER REQUIREMENTS watts	CREW SKILLS (CODE)	ENVIRONMENT REQUIREMENTS	TIME REQUIREMENTS	EXPERIMENT FREQUENCY	DATA REQUIREMENTS
1.4.1 NEUROLOGICAL FUNCTION										
Human Vestibular Function	121	(265)	1.1	(39)	180	Technician (1)	215 ± 100 lumen/m^2 (20 ft-candles)	45 min	3 days	4 kbs
EEG Neurological Exp.	12	(27.3)	0.15	(5)	4.4	Technician (1)		2 hr	daily	25 kbs
Sleep Monitoring	12	(27.3)	0.15	(5)	4.4	Technician (1)		8 hr	daily	25 kbs
Circadian Rhythms	35	(80)	0.3	(11)	5	Technician (1)		30 min	1 week	
1.4.2 CARDIOVASCULAR FUNCTION										
Use of LBNP	15	(32.5)	0.3	(11)	2.5	Medical Doctor (13)		66 min	3 days	3 kbs
Vectorcardiogram	2.5	(5.3)	0.04	(1.2)	2.5	Technician (1)		60 min	3 days	3 kbs
Arterial Pressure Control System	18	(40)	0.3	(11)	50	Medical Doctor (13) Technician (1)		50 min	1 week	
Intraocular Blood Pressure	0.07	(0.15)	-	-	-	Technician (1)		10 min	daily	
Cardiac Dynamics – Ballistocardiogram	0.5	(1)	-	-	60	2 Technicians (1)		30 min	Intermittent	1800 bps
Peripheral Arterial Reactivity	0.9	(2)	0.001	(0.04)	12	Technician (1)		15 min	5-10 days	
1.4.3 RENAL FUNCTION										
Renal Blood Flow	275	(62)	0.13	(4.6)	100	Medical Doctor (13)		60 min	daily	200 bits/day
Indices of Renal Function	27	(60)	0.2	(7)	210	Technician (1)		2 hr	1 week	
Renal Calculus Formation in Rats	65	(140)	0.5	(17)	10	Technician (1)		10 min	daily	
Renal Infection in Rats	90	(195)	0.4	(14)	5	Technician (2)		30 min	daily	
1.4.4 NUTRITION & METABOLIC FUNCTION										
Mineral Balance	2	(5)	0.03	(1)	10	Technician (1)		30 min	daily	Log
Biochemistry of Body Fluids	22	(50)	0.15	(5)	50	Technician (1) Biochemist (3)		2 hr	4 days	
Gastrointestinal Motility and pH	18	(40)	0.15	(5)	25	2 Technicians (1)		50 min	weekly	
1.4.5 MUSCULOSKELETAL FUNCTION										
Bone Densitometry	TBD	TBD	TBD	TBD	TBD (0.1 sec exp)	Crew (Self)	Lead-shielded room	30 min	2 days	TBD
Specimen Mass Measurement	20	(42)	0.03	(0.9)	2	Technician (1)	No rolling & tumbling	75 min	daily	Hand logged
Deconditioning Indices – EMG	27	(60)	0.2	(7)	10	Technician (1)		20 min	weekly	
1.4.6 PULMONARY FUNCTION										
Metabolic Activity	70	(150)	0.4	(14)	48	Technician (1)		5 hr	weekly	1000 bps
Body Mass Measurement	17	(38)	0.4	(14)	2	Technician (1)	Nominal 0-g maintained	2 min.	daily	Log
1.4.7 HEMATOLOGIC FUNCTION										
Blood Volume and Red Cell Life Span	22	(50)	0.3	(10)	30	Technician (1)	Total rad. dose 780 mrad	2 hr	weekly	

Table 1-2. Experiment Requirements Summary, Contd

EXPERIMENT	MASS (WEIGHT) kg	MASS (WEIGHT) (lb)	VOLUME m^3	VOLUME (ft^3)	POWER REQUIREMENTS (watts)	CREW SKILLS (CODE)	ENVIRONMENT REQUIREMENTS	TIME REQUIREMENTS	EXPERIMENT FREQUENCY	DATA REQUIREMENTS
1.4.7 HEMATOLOGIC FUNCTION, Contd										
Red Blood Cell Metabolism	18	(40)	0.06	(2)	20	Technician (2)				
Special Hematologic Effects	9	(20)	0.1	(4)	20	Technician (2)				
Blood Coagulation	7	(15)	0.1	(4)	-	Technician (2)		30 min	4 days	Color film
1.4.8 MICROBIOLOGY & IMMUNOLOGIC FUNCTION										
Human Immunity – in vitro Effects	23	(50)	0.15	(5)	100	Technician (2)				Log
Cytogenic Studies of Blood	14	(30)	0.1	(4)	50	Technician (2)				Log
Microbial Profiles of Crew Members	14	(30)	0.02	(0.7)	15	Technician (2)		6 hr	weekly	Log
1.4.9 ENDOCRINE FUNCTION										
Endocrine Assays	50	(110)	0.3	(10)	220	Technician (22)		15 min	4 days	
Thermoregulation	23	(50)	0.2	(7)	12	Technician (1)		6 hr	weekly	
Gonad Histopathology	7	(15)	0.1	(4)	-	Technician (2)		30 min	weekly	
1.4.10 CLINICAL/THERAPEUTIC FUNCTION										
Exercise Conditioning	30	(66)	0.6	(21)	17	None		90 min	daily	
Wound Healing	50	(106)	6.7	(234)	190	Technician (2)	Variation in g level desirable	1 hr	3 days	Film
1.4.11 ENVIRONMENTAL FACTORS AND SURFACE										
Airborne/Contamination	28	(62)	0.1	(4.0)	1260	2 Technicians (2)		20 min - sample collect. 10 hr - analysis	weekly	Manual log
Ionizing Radiation (High-Z particles)	<5	(<11)	0.005	(<0.2)	None	Technician with Radiobiology Training		8 hr	monthly	TBD

Table 1-3. Medical Research Program

Section	Title
1.4.1	Experiment Class: Neurological Function
1.4.1.1	Experiment: Human vestibular function
1.4.1.2	Experiment: Neurological experiment - EEG
1.4.1.3	Experiment: Sleep monitoring
1.4.1.4	Experiment: Circadian rhythms
1.4.2	Experiment Class: Cardiovascular Function
1.4.2.1	Experiment: Use of LBNP device to prevent CV deconditioning
1.4.2.2	Experiment: VCG
1.4.2.3	Experiment: Arterial pressure control system
1.4.2.4	Experiment: Intraocular arterial blood pressure
1.4.2.5	Experiment: Cardiac dynamics-ballistocardiograph
1.4.2.6	Experiment: Peripheral arteriolar reactivity
1.4.3	Experiment Class: Renal Function
1.4.3.1	Experiment: Renal blood flow
1.4.3.2	Experiment: Indices of renal function
1.4.3.3	Experiment: Renal calculus formation in rats
1.4.3.4	Experiment: Renal infection in rats
1.4.4	Experiment Class: Nutrition and Metabolic Function
1.4.4.1	Experiment: Mineral balance
1.4.4.2	Experiment: Biochemistry of body fluids
1.4.4.3	Experiment: Gastrointestinal motility and pH
1.4.5	Experiment Class: Musculoskeletal Function
1.4.5.1	Experiment: Bone densitometry
1.4.5.2	Experiment: Specimen mass measurements

Table 1-3. Medical Research Program, Contd

Section	Title
1.4.5.3	Experiment: Deconditioning indices - EMG
1.4.6	Experiment Class: Pulmonary Function
1.4.6.1	Experiment: Metabolic activity
1.4.6.1	Experiment: Body mass measurement
1.4.6.3	Experiment: Ventilatory mechanics
1.4.6.4	Experiment: Blood and ventilatory gas exchange
1.4.7	Experiment Class: Hematologic Function
1.4.7.1	Experiment: Blood volume and red cell life span
1.4.7.2	Experiment: Red blood cell metabolism
1.4.7.3	Experiment: Special hematologic effects
1.4.7.4	Experiment: Blood coagulation
1.4.8	Experiment Class: Microbiology and Immunologic Function
1.4.8.1	Experiment: Human immunity - in vitro aspects
1.4.8.2	Experiment: Cytogenic studies of blood
1.4.8.3	Experiment: Microbial profiles of crew members
1.4.9	Experiment Class: Endocrine Function
1.4.9.1	Experiment: Endocrine assays
1.4.9.2	Experiment: Thermoregulation
1.4.9.3	Experiment: Gonad histopathology
1.4.10	Experiment Class: Clinical/Therapeutic Function
1.4.10.1	Experiment: Exercise conditioning
1.4.10.2	Experiment: Wound healing

Table 1-3. Medical Research Program, Contd

Section	Title
1.4.11	Experiment Class: Environmental Factors
1.4.11.1	Experiment: Airborne and surface contamination
1.4.11.2	Experiment: Radiation effects

1.4.1 NEUROLOGICAL FUNCTION

1.4.1.1 Human Vestibular Function

1.4.1.1.1 Scientific or Technical Objectives. This experiment is intended to acquire data pertinent to (1) an understanding of the functions of gravity receptors in the prolonged absence of gravity, and (2) establishing the validity of predictions from ground-based studies for astronaut habitation to rotating space environments and to the specification of optimal rates and radii of these environments.

1.4.1.1.2 Description. This experiment compares (1) the pre- and post-flight responses to canal stimulation with inflight responses using a rotating litter chair device and (2) pre- and post-flight measures of spatial localization with inflight measures using the static tilting mode of the device. Experiment tests are grouped as follows:

a. Canal Stimulation Tests

 1. Threshold: Subject's verbal reports of apparent movement of visual target in response to chair rotational acceleration.

 2. Susceptibility: Verbal reports by both subject and experimenter of clinical symptoms as trained. Number of specific head movements; questionnaire; angular velocity of rotating litter chair.

b. Spatial Localization Tests

 1. Tilt chair mode: Requires observer's verbal reports of subject's settings on otolith test goggle and rod and sphere, as well as of test conditions.

 2. Tilt litter mode: Requires observer's verbal reports of subject's setting on rod and sphere.

The equipment consists of: an electric-motor driven, servo-controlled, precision rotating chair device which can also tilt in pitch and roll axes in static mode; Apollo otolith test goggle (OTG) and biteboards; handheld reference sphere, magnetic

pointer, magnetic strap and readout device; questionnaire card, control console, accelerometer and storage cabinet. The equipment is summarized in Table 1-4.

1.4.1.1.3 Observation/Measurement Program. The inflight testing program data requirements are listed in Table 1-5. The testing program consists of the following:

a. Canal Stimulation Test. Six 30-minute tests by each astronaut, performed no more frequently than every other day, equal spacing preferred. Three astronauts will participate as subjects or experimenters.

b. Space Localization Test. Three 45-minute tests by each astronaut with equal mission spacing preferred. May not be performed on same day as Canal Stimulation Tests. Three astronauts will participate by alternating as subjects and experimenters, each acting as subject within a 16-hour period; otherwise the statistical nature of the data will be degraded.

1.4.1.1.4 Interface, Support and Performance Requirements. No spacecraft maneuver should be performed during the experiment test series; elimination of noise which would provide orientation clues to test subject is a prerequisite. The equipment will be designed and tested to conform to the launch and spacecraft operational constraints. There is a physiological requirement for an ambient temperature for the test subject of 295 ± 3°K (75 ± 5°F). A specified lighting of 215 ± 100 lumen/m^2 (20 ± 10 footcandles) is required.

1.4.1.1.5 Potential Role of Man. Astronauts sufficiently trained in the methods and operation of this experiment will satisfy the skill requirements of experimenter and subject. Approximately 25 hours of preflight training for each crew member are required. The crew will perform and document the setup, conduct, and cleanup of the experiment. Operation includes routine maintenance tasks and serving as both experimenter and test subject. They will operate and control voice and data monitoring.

1.4.1.6 Available Background Data

a. Governing Protocol, Neurophysiology, M130, NASA DB-55-67-M130, August 1967.

b. Experiment Implementation Plan for Experiment M131 Human Vestibular Function, NASA DB-56-67-M131, July 1968.

c. Miller, E. F. and Graybiel, A., A Standardized Laboratory Means of Determining Susceptibility to Coriolis (Motion) Sickness, NASA Order R-93, T-81533, February 1969.

Table 1-4. Human Vestibular Function Equipment Summary

Item	Weight kg (lb)	Volume m^3 (ft^3) Stored	Volume m^3 (ft^3) Operate	Dimensions cm (in) Stored	Dimensions cm (in) Operate
Rotating Litter Chair	23 (50)	0.10 (3.5)	0.9 (31.0) with subject	55 x 65 x 25 (22 x 26 x 10)	
Base of Chair and Motor	46 (100)	0.12 (4.2)	0.12 (4.2)	55 dia. x 40 h (22 dia. x 16 h)	Same
Control Console	23 (50)	0.05 (1.7)	0.05 (1.7)	30 x 30 x 50 (12 x 12 x 12)	Same
Protective Soft Covers	2 (4)				
Misc. Container & Equipment	27 (60)	0.05 (1.7)	0.05 (1.7)	30 x 30 x 50 (12 x 12 x 12)	Same
Otolith Test Goggle					
Biteboards					
Magnetic Pointers					
Reference Sphere					
Questionnaire					
Power and Data Cables					
Accelerometer					
Head Proximity Device					
Response Matrix					
TOTALS	121 (265)	0.32 (11.2)	1.1 (39)		

Table 1-5. Human Vestibular Function Data Measurement Requirements

Measurement	Data Type	No. of Channels	Samples/Sec.
Monitor Motor Current	Analog	1	320
Monitor Motor Speed	Analog	1	40
Accelerometer Readout	Analog	6	1.25
Head Motion Acknowledgement	Analog	4	1.25
Cadence Signal Acknowledgement	Analog	1	1.25
+ Converter Voltage	Analog	1	1.25
- Converter Voltage	Analog	1	1.25
Ambient Temperature	Analog	1	1.25
Experiment State - OGI/MS	Bilevel	1	10
"Question Subject" Lamp - On/Off	Bilevel	1	10
Experiment Identification	Bilevel	1	10
Subject Identification	Bilevel	2	10
OGI Response Matrix	Bilevel	2	10
MS Response Matrix	Bilevel	16	10
RPM Range	Bilevel	3	10

1.4.1.2 Neurological Experiment - EEG

1.4.1.3 Sleep Monitoring

1.4.1.4 Circadian Rhythms

1.4.2 CARDIOVASCULAR FUNCTION

1.4.2.1 Use of a Lower-Body Negative Pressure (LBNP) Device to Prevent Cardiovascular Deconditioning

1.4.2.1.1 Scientific or Technical Objectives. The purpose of this experiment is to study the effects of a periodically applied LBNP device on maintenance of cardiovascular conditioning. It has been observed in space flight and in ground-based bedrest water-immersion studies that a decrement in cardiovascular reactivity is generally associated with the absence of the usual gravitational hydrostatic stresses. It has been demonstrated that the application of subambient pressures to the body

surface caudal to the diaphragm produces a stress and consequent reactions to the cardiovascular system which are similar to being in the normagravic environment.

1.4.2.1.2 Description. Inflight data will be taken for predicting the degree of orthostatic intolerance and impairment of physical capacity to be expected following return to a 1-g environment. This will require the use of LBNP equipment. This device will enable the application of negative pressure to the lower abdomen and legs. Leg plethysmographs will measure leg volume before, during and after the application of negative pressure. The projected procedure, therefore, may be referenced to the time required in LBNP to change the course of deconditioning. Heart rate and blood pressure will be monitored. Table 1-6 lists the equipment required for the experiment.

1.4.2.1.3 Observation/Measurement Program. Subjects undergoing LBNP will be instrumented for the measurement of ECG, heart rate, body temperature, blood pressure, and with cage capacitance plethysmographs for the measurement of percent change in leg volume. Instrumented subjects will be sealed in the LBNP device. Measurements will be taken during a 5-minute baseline phase, a 15-minute negative pressure phase, and a final 5-minute recovery phase. A pressure of 40 to 50 mm Hg below ambient will be applied to the lower body during the negative pressure phase. All measurements will be made continuously throughout the procedure, excepting blood pressure which will be made at 30-second intervals. The subject should remain relatively immobile during the 25 minutes that the recordings are being made. During the procedure the blood pressure might be expected to fall to approximately 90/50 and the leg volume to increase to about 4 to 5 percent above normal.

Two subjects should be tested every two days for the first two weeks, then weekly for the mission duration. Tests should be performed at least three hours after eating. Total duration of each experimental run is approximately 66 minutes.

Table 1-6. Equipment Summary

Equipment Item	Weight kg (lb)	Volume m^3 (ft^3)	Power (watts)
Lower Body Negative Pressure Device	7 (15)	0.3 (10.6)	56
Leg Volume Plethysmographs	1.5 (3.3)	0.03 (1.0)	0.2
Blood Pressure Assembly	2.3 (5.0)	0.015 (0.5)	0.25
Stowage Container 60 x 75 x 30 cm (24 x 30 x 12 in.)	4.3 (9.5)	0.15 (5.0)	
Vectorcardiogram	2.4 (5.3)	0.03 (1.06)	2.5 (28 Vdc)
Ear Canal Temperature Probe	0.05 (0.1)		

During flight the cardiovascular response of subjects undergoing LBNP conditioning will be compared to that of nonconditioned subjects in comparable cardiovascular tests not using LBNP.

1.4.2.1.4 Interface, Support and Performance Requirements. Measurement facilities for the LBNP device and for all parameters monitored during the procedure will be supplied by the Biomedical Measurement Unit and the CORE. The CORE data management system is designed to handle the frequencies of the various parameters and process them for recording and telemetry. One experimenter is sufficient for the procedure. Table 1-7 lists the data requirements.

1.4.2.1.5 Potential Role of Man. Man will be used as both the subject and experimenter for this experiment. Approximately 13 hours of preflight training are anticipated for the experimenter and 5 hours each for the subjects. An MD must be present during experiment.

1.4.2.1.6 Available Background Data

a. Governing Protocol, Cardiovascular Function, NASA DB-69-68-MO90, April, 1968.

b. Experiment Implementation Plan for Manned Space Flight Experiment MO92, Inflight LBNP, NASA DB-74-68-MO92, May, 1968.

1.4.2.2 VCG

1.4.2.3 Arterial Pressure Control System

1.4.2.4 Intraocular Arterial Blood Pressure

1.4.2.5 Cardiac Dynamics – Ballistocardiograph

1.4.2.6 Peripheral Arteriolar Reactivity

1.4.3 RENAL FUNCTION

1.4.3.1 Renal Blood Flow

1.4.3.1.1 Scientific or Technical Objectives. Experiment objectives are:

a. To assess the renal and fluid/electrolyte changes incident to space flight.

b. To investigate some of the mechanisms potentially responsible for changes in urine volume during weightless exposure.

c. To understand and develop countermeasures to plasma volume reductions occurring during space flight.

Table 1-7. Data Requirements

Measurement	DATA ACQUISITION						DATA DISPOSITION			XMISSION		
	Type	Analog Freq (or Msmts per Specimen)	Measurement Duration (Min.)	Msmts/Exp.	Measurement Range	Smallest Increment	Display	Processing	Storage	Type	% of Data	Daily
LBNP Pressure Diff.	D		15	10	0-60mm Hg	0.1	Gauge		Manual	D	100	X
Left Leg Volume	A	0-1 Hz	25	Cont	0-10%	0.1%	Meter	A to D	Dig. Tape	D	50	X
Right Leg Volume	A	0-1 Hz	25	Cont	0-10% Change	0.1%	Meter	A to D	Dig. Tape	D	50	X
Blood Pressure Cuff	D	Every 30 sec.	55	30	90/50-150/100mm Hg	1 mm Hg	Gauge		Manual	D		X
Microphone Out.	A		55	30	Bilevel		Ear Phone					
VCG	A	0-100 Hz	25	Cont	0-5mV	0.1mV	HR display on meter	A to D	Dig. Tape	D	10	X
Body Temp.	A	0-1 Hz	25	Cont	310±2°K (98.6±3°F)	0.1°K (0.1°F)	Meter	A to D	Dig. Tape	D	10	X
Voice	A	100 Hz - 3 kHz	66	Cont					Audio Tape	A	100	X
Exp/Subj Iden.	D	(1)	1	1					Manual	D	100	X
Timing-Mission	D		66	Cont	0-100 min	1 sec	Clock		Manual	D	100	X
Temp. Amb.	D	(2)	2 sec	2	295±2°K (72±3°F)	0.1°K (0.1°F)	Gauge		Manual	D	100	X
Press. Amb.	D	(2)	25		32±3.5 kN/m^2 (4.7±0.5 psi)	0.35 kN/m^2 (0.05 psi)	Gauge		Manual	D	100	X

1.4.3.1.2 Description. Reductions in plasma volume may result from a diuresis produced by an inhibition of the release of ADH and aldosterone by volume receptors stimulated by an initial increase in thoracic blood. Some investigators have suggested that changes in renal blood flow may play a role.

Three unconditioned subjects will be used for the experiment. Twenty-four hour urine volumes will be measured daily for each subject. Two aliquots will be removed from each 24-hour sample; one will be frozen and returned for ADH and aldosterone analysis; the other will be stored (frozen at 253°K or lower) for weekly measurements of specific gravity, Na, and pH.

Renal blood flow will be measured once per week on each subject by para-aminohippuric acid (PAH) clearance. PAH is administered intravenously. A urine sample is voided immediately prior to administration and used as a blank. A second sample is voided at a given period of time following PAH injection. Simultaneous with this collection, a venous blood sample is taken. Both blood and urine are analyzed spectrophotometrically for PAH. The two urine samples may be discarded after analysis and not mixed with the 24-hour sample; however, their volumes should be added to the 24-hour total.

1.4.3.1.3 Observation/Measurement Program. The experiment will be conducted during the first three weeks of the crew cycle. For each of the three experimental subjects, 24-hour urine volumes will be measured daily. An aliquot will be removed, frozen and returned for postflight analysis of ADH and aldosterone. Another aliquot will be used to determine specific gravity, Na and pH. A refractometer is used to determine the specific gravity from which the solute concentration can be calculated. Urine Na and pH are measured electroanalytically with specific electrodes. Na is related to volume in reflecting aldosterone activity. Urine pH reflects not only the pH of the blood and the status of the blood buffer systems but also the Na^+, K^+, and H^+ relationship in renal tubular function.

PAH is injected into the venous blood and a subsequent blood sample is compared in a formula with the amount excreted. The clearance of PAH consequently can be used as a measure of renal blood flow. The concentration of PAH in both blood and urine is measured with a spectrophotometer.

Urine sampling and pH and Na analysis require 60 min/measurement day, including setup and stowage. The PAH renal clearance requires 120 min/measurement day.

Table 1-8 indicates the equipment required for this experiment. Urine collection, measurement, and sampling are included in the function of the Waste Management System. The necessary expendable supplies are: sample containers (urine and blood), syringes, disinfectant, gauze sponges, clinical centrifuge tubes, and PAH.

Table 1-8. Renal Blood Flow Equipment Summary

Item	Weight kg (lb)	Volume m^3 (ft^3)	Power W	Available Model/Comments
Electroanalytical System	4.5 (10)	0.015 (0.5)	10	Measures pH and radical concentrations of blood and urine
Freezer (203°K)	9 (20)	0.03 (1)	40	Stores blood samples
Spectrophotometer	4.5 (10)	0.015 (0.5)	20	
Refractometer	0.3 (0.7)	0.001 (0.02)		AO's Goldberg
Misc. Fluid-Transfer Equipment	4.5 (10)	0.06 (2)		Provides reusable containers for biomedical fluid transfer.
Clinical Centrifuge	2.7 (6)	0.01 (0.3)	30	
Timer	2 (5)	0.01 (0.3)	1	Console Mounted Timer
TOTALS	27.5 (62)	0.17 (4.6)	100	

1.4.3.1.4 Interface, Support and Performance Requirements. The experiment must start within the first or second day of the crew cycle before significant changes occur in fluid balance. Urine sampling may be interrupted on two nonsuccessive occasions within a 10-day test period. Not more than 10 days should elapse between renal blood flow measurements.

The Waste Management System will be used to measure urine volume and dispense a measured urine sample. Frozen urine samples must be accommodated during re-entry.

The data output rate will be approximately 30 bits/week for the clearance experiment and 200 bits/day for urine collection and analysis.

Weight of the experiment equipment is 27.5 kg (62 lb) and operational volume is 0.17m^3 (4.6 ft^3). Power requirements are 100 watts for approximately 60 minutes/day.

1.4.3.1.5 Potential Role of Man. A medical technician is required for the blood sampling, venous injection of PAH, and analysis of blood and urine samples. Three unconditioned crewmen are needed as subjects. No special training is required.

1.4.3.1.6 Available Background Data. Experiment 1-114, Requirements Study for a Biotechnology Laboratory for Manned Earth-Orbiting Mission, Phase II, Volumes I and II, MDC G0620, 1970.

1.4.3.2 Indices of Renal Function

1.4.3.3 Renal Calculus Formation in Rats

1.4.3.4 Renal Infection in Rats

1.4.4 NUTRITION AND METABOLIC FUNCTION

1.4.4.1 Mineral Balance

1.4.4.1.1 Scientific or Technical Objectives. Definition and quantitative assessment of the gains and losses from the body of various biochemical constituents, particularly water, calcium, and nitrogen, during spaceflight.

1.4.4.1.2 Description. Musculoskeletal deterioration cannot be tolerated by the human body for indefinite periods of time. A determination of the rates of chemical imbalance may allow specific countermeasures to be taken. This experiment may also indicate whether manipulation of various dietary constituents can be an effective countermeasure.

Precise measurement of the input and output of calcium and nitrogen, together with other biochemical constituents in samples of urine, feces, sweat and food will be carried out to quantitate rates of gain or loss in a spacecraft mission lasting up to 50 days. Major items of hardware required for this experiment are: 1) Urine Sampling and Volume Measurement System installed for easy crew access; 2) Specimen Mass Measurement Device using a linear spring/mass pendulum, the period of which is electronically determined by the mass of the measured body; 3) Body Mass Measurement Device identical in principal to the Specimen Device; and 4) a Waste Management System integrated with the urine measurement system and including a fecal collector and a dryer.

Each member of the crew must record dietary and fluid intakes and must record, measure, and sample each micturition. Fecal eliminations must be recorded, weighed and dried; sweat must be sampled once per week.

1.4.4.1.3 Observation/Measurement Program. The experiment has three phases: 1) preflight, 15 days maximum; 2) inflight, up to 60 days; and 3) postflight, 15 days maximum, beginning immediately postflight. The inflight portion of the experiment protocol consists of the following:

a. Exercise: Level of physical activity will be governed by the regular pattern established by the crew.

b. Body weight: Body mass measurement daily upon arising, after micturition.

c. Diet: Calcium intake must be made as constant as possible within a range of 800-1000 mg/day during all phases of the experiment. The diet will be the Apollo-type menu of freeze-dehydrated and otherwise dried or processed foods of known composition. A record of food consumed will be maintained.

d. Fluid Intake: A water measuring device for drinking and food reconstitution will be utilized, and consumption by each crew member recorded. The crew member will log the counter readings at each usage.

e. Specimen Collection:

1. Urine and Feces - The Urine Sampling and Volume Measurement Systems will be utilized to measure the volume of each micturition and to collect a known percentage of each micturition for accumulation into a 24-hour sample. Provision must be made for identifying each astronaut, and the time and volume of each micturition. The wet weight of stools will be determined by mass measurement. Crew identification, time of defecation, and mass of sample will be recorded. The relationship between dietary intake and fecal excretion will be deduced from the appearance of a fecal dye marker, ingested at the beginning of the flight and at each six-day interval thereafter.

2. Blood - Routine analysis of 50-ml blood samples will be made inflight if appropriate analysis equipment is available.

3. Food - The mass of all food items, rehydratable or otherwise, will generally be known in advance of flight. It is only necessary for the crew members to keep an accurate log of their daily consumption and to determine and record the wet and dry mass of any leftover food to within 1%.

All inflight samples will be preserved by vacuum drying at no greater than 313°K (40°C) until 95% or more of the moisture has been removed.

Table 1-9 indicates the parameters that will be monitored.

1.4.4.1.4 Interface, Support and Performance Requirements. Equipment required for this experiment, including the urine volume measurement and sampling system, the specimen and body mass measurement devices, fecal dryer and urine sample freezer, is all assumed to be part of the CORE. The only additional equipment would be sample containers and log books. Crew participation is expected to be 30 min/day in addition to the time required for eating and elimination. Estimated weight of the experiment, exclusive of the support equipment, is 2 kg/mo (5 lb/mo). Power usage is estimated at 10 watts/day.

1.4.4.1.5 Potential Role of Man. Flight crew members will receive a thorough indoctrination in addition to the preflight briefing. Crew members are required for

Table 1-9. Nutrition and Metabolic Function Measurements

Parameter	Sample	Range	Sample Size
Calcium	Serum	4.5-5.7 mEq/l	0.5 ml
	Urine	0.1-0.4 g/24 hr	10.0 ml
	Feces	0.3-1.3 g/24 hr	1.0 ml
	Food	0.8-1.0 g/24 hr	1.0 g
	Sweat		
Phosphorus	Serum	2.5-4.8 mg%	0.5 ml
	Urine	0.8-1.5 g/24 hr	1.0 ml
	Feces	0.9-1.7 g/24 hr	1.0 g
	Food	1.4-1.55 g/24 hr	1.0 g
	Sweat		
Magnesium	Serum	1.52-2.4 mEq/l	1.0 ml
	Urine	4.1-16.4 mEq/24 hr	1.0 ml
	Feces	0.12-0.36 g/24 hr	1.0 g
	Food	0.14-0.22 g/24 hr	1.0 g
	Sweat		
Sodium & Potassium	Serum	135-143 mEq/l	0.1 ml
	Urine	150-197 mEq/24 hr	0.5 ml
	Food	2.5-3.5 g/24 hr	1.0 g
	Sweat		
Chloride	Serum	98-110 mEq/l	1.0 ml
	Urine	10-15 g/24 hr	1.0 ml
	Sweat		
Total Nitrogen	Urine	10-18 g/24 hr	1.0 ml
	Feces	0.7-2.1 g/24 hr	1.0 g
	Food	14.0-17.6 g/24 hr	1.0 g
	Sweat		
Creatine	Urine		
Creatinine	Urine	1-1.5 g/24 hr	1.0 ml
Hydroxyproline	Urine	1.5 mg/24 hr	5.0 ml
Urea	Urine	25-35 g/24 hr	1.0 ml
Chromium	Feces		
Amino Nitrogen	Urine	100-150 mg/24 hr	2.0 ml
Osmolality	Urine	50-1200 mOsm/l	2.0 ml

the collection of baseline experimental data during the preflight control period when urinary and fecal samples will be recovered from each astronaut. No particular crew skills are required for this experiment.

1.4.4.1.6 Available Background Data. Experiment Implementation Plan for Experiment MO71, Mineral Balance, NASA DB-76-68 MO71A, October 1968.

1.4.4.2 Biochemistry of Body Fluids

1.4.4.3 Gastrointestinal Motility and pH

1.4.5 MUSCULOSKELETAL FUNCTION

1.4.5.1 Bone Densitometry

1.4.5.1.1 Scientific or Technical Objectives. To assess the skeletal status of crew members before, during and after space flight by direct photon absorptiometry. The measurements are necessary, for decalcification of bones observed in hypodynamic and hypogravic states presents a serious biomedical problem for prolonged space flights. It may affect the structural integrity of the skeleton during or after such flights; blood chemistry could be affected and ectopic calcification, principally of the urinary tract, may develop. The study will permit assessment of the magnitude of the skeletal changes in flight, and evaluation of the necessity for or consequences of possible remedial action.

1.4.5.1.2 Description. Crew members will be the subjects. The photon absorptiometric technique is nonhazardous, and the measurements are relatively simple, straight-forward and accurate. Each subject will be able to make the measurements on himself or with minimal assistance.

Inflight hardware will consist of two assemblies: a mechanical scanner with a radionuclide source and a scintillation detector probe, and an electronics package for handling the signals from the detector.

A dual photon (dichromatic) technique will be used with sealed sources of low-energy radionuclides providing the photon beam. At present I^{125} (27.4 keV) and Am^{241} (60 keV) appear to be the most suitable sources; however, other radionuclides are being evaluated to optimize the procedure. Miniaturized nuclear instrumentation and a small folding or telescoping scanner will be used in the bone-scanning system. The subject will place the area to be measured in a holder to insure relocation, and activate the scanner which will pass several times across each location. Changes in bone density will be reflected in the data output, which will be used to determine relative degree of mineral loss.

1.4.5.1.3 Observation/Measurement Program. Measurements will be made on both weightbearing (tibia and os calcis) and non-weightbearing (humerus, radius and ulna) bones of crew members. Onboard measurements will be made every two days, and will require abqut 30 minutes per subject per occasion. Several pre- and post-flight measurements will also be made for comparison. It is important that the diet during ground control tests be essentially similar to that during flight.

1.4.5.1.4 Interface, Support and Performance Requirements. Requirements are minimal. The instrument to be supplied by the principal investigator will be located in the Diagnostic X-ray Facility (see Radiobiology Unit), which will provide the necessary physical, electrical, etc., requirements. The signal output from the instrument will be coupled to the CORE Data Management Unit for readout and/or analysis.

Return of the radionuclide bone-scanning device is required.

1.4.5.1.5 Potential Role of Man. Crew members can make their own inflight measurements or with minimal assistance after about one hour of preflight training. Measurements are to be made once every two days and will require about 30 minutes per subject per occasion.

1.4.5.1.6 Available Background Data. The sole source of background data is a flight proposal (T-045), by the same title, provided by NASA, ARC.

1.4.5.2 Specimen Mass Measurements

1.4.5.3 Deconditioning Indices - EMG

1.4.6 PULMONARY FUNCTION

1.4.6.1 Metabolic Activity

1.4.6.1.1 Scientific or Technical Objectives. Primary objectives of this experiment are:

a. To determine if man's metabolic effectiveness in doing mechanical work is progressively altered by exposure to the space environment.

b. To determine metabolic cost of identical operational activities when man is deprived of the benefit of Earth gravity as compared to the cost on Earth.

Secondary objectives of this experiment are:

a. To evaluate ground-based reduced-gravity simulators.

b. To evaluate the bicycle ergometer as an exerciser for long-duration missions.

c. To determine the difference in metabolic cost between suited and nonsuited work in a zero-g environment.

d. To develop techniques for evaluation of crew well-being and performance during EVA activities.

1.4.6.1.2 Description. Metabolic rate (O_2 consumption, CO_2 production, and respiratory quotient) is to be measured during rest, calibrated exercise (bicycle ergometer), and operational-type tasks. The resting metabolic rate and metabolic rate during calibrated exercise are to be measured in a nonsuited and in a suit pressurized 25 kN/m^2 (3.7 psi) above the workshop environment. In order to evaluate results obtained in flight, ground-based data are to be obtained on each crew member during all the experimental configurations. Additional ground-based physiological data are to be obtained in separate studies, including bed rest, water immersion, reduced gravity simulations, and exercise training protocols.

Energy production can be calculated using indirect calorimetry which measures the O_2 consumed. The energy released per mol of O_2 consumed can be determined from an analysis of the respiratory quotient, which requires that CO_2 production (during steady-state conditions) be measured simultaneously with O_2 consumption. Monitoring energy production over time will allow a calculation of the metabolic rate. This is accomplished by the basic equipment unit of this experiment, the metabolic analyzer. This device has the following characteristics:

a. A highly accurate, wide dynamic range, compact flowmeter for measuring respiration rate with necessary correction for STPD in any habitable environment.

b. An accurate, compact gas sensor which simultaneously measures oxygen, carbon dioxide, nitrogen and water.

c. Compact data handling system.

d. System response that follows non-steady-state physiological conditions.

To supplement measurement of metabolic rate, the following physiological parameters will be measured simultaneously: heart rate, blood pressure, respiration rate, and body temperature. In addition, timed respiratory volumes will be measured periodically throughout the flight. Table 1-10 indicates the equipment required for the experiment.

1.4.6.1.3 Observation/Measurement Program. For this experiment, the measurement of O_2 consumption and CO_2 production will be necessary in the following range of environments:

a. Pressure: 34-100 kN/m^2 (5.0 - 14.7 psi) unsuited, 60-130 kN/m^2 (8.7 - 18.4 psi) suited.

Table 1-10. Metabolic Activity Equipment Summary

Equipment Item	Weight kg (lb)	Volume m^3 (ft^3) Stored / Operation	Dimensions cm (in.) Stored / Operation	Power
CONTAINER 1 Metabolic Device and Electrical Cable	16 (35)	0.05 (2.0) 0.05 (2.0)		20 W 28 Vdc
*CONTAINER 1-A Expendables: LiOH O_2	20 (44) 2.7 (6)	0.05 (2.0) 0.05 (2.0)		
CONTAINER 2 Maintenance and Constant Work Tasks (including tools)	10 (22)	0.07 (2.5) 0.07 (2.5)	25x45x60 (10x18x24)	
CONTAINER 3 Ergometer and Electrical Cable	10 (22)	0.07 (2.5) 0.5 (18.0)	30x40x60 (12x15x24) 45x120x90 (18x48x36)	15 W, 28 Vdc 5600 W (2000 Btu/hr) output
CONTAINER 4 Modified Helmet Face Masks (3) Respiratory Hoses (4)	3.5 (7.7) 0.35 (0.77) 0.5 (1)	0.05 (2.0) 0.05 (2.0) 0.01 (0.36) 0.01 (0.48) 0.01 (0.48)		
MISCELLANEOUS EKG Electrodes (3 sets) Body temperature (sensors (3) Paper Tissues Electrode Cleaning Kit	0.5 (1)			0.1 W
TOTAL	70 (154)	0.35 (12)		

*Container is optional, depending upon open or closed Metabolic Measuring System. LiOH expendables and container will not be required for open system, reducing the weight and volume requirements. O_2 required for open system will be stored in ECS.

b. Composition: 100% O_2, 30% N_2.

c. Ambient temperature: 297 ± 3°K (75 ± 5°F).

During the flight data acquisition period for a 28-day mission, each crewman will spend 15 hours (5 hours/experiment x 3 repeats) as a subject and 7 hours (2.3 hours/experiment x 3 repeats) as an observer, for a total time of 66 hours (22 hours/crewman x 3 crewmen). The experiment is to be repeated four times during a 56-day mission, for a total of 88 hours/crewman. These times are proportioned among the three phases of the experiment as shown in Table 1-11.

Some special considerations are: experiment should not be performed until two hours after heavy exercise; the ergometry phase should be scheduled at least three or four hours after eating; each crewman's experiment period should be scheduled at the same time on all experiment days.

1.4.6.1.4 Interface, Support and Performance Requirements. There are no special flight requirements or trajectory characteristics other than those that may be needed to provide a stable thermal environment during experimental periods. A high-pressure oxygen source is needed for the metabolic device and suit pressurization system. O_2 requirements are approximately 100 liters at STPD for each of 27 runs. Other experiment interface requirements are: weight, 70 kg (150 lb); volume, 0.35 m^3 (12 ft^3); power, 48 watts. Data measurement requirements are summarized in Table 1-12.

1.4.6.1.5 Potential Role of Man. No special skills are required of the astronauts. The astronaut will be trained in all required procedures during baseline testing. Approximately 26 hours of preflight training per astronaut is required.

1.4.6.1.6 Available Background Data. Experiment Implementation Plan, Metabolic Activity, NASA DB-72-68-M171, April 1968.

Table 1-11. Experiment Time Breakdown for 28-Day Mission

Experiment Phase	Subject Time	Observer Time	Total Crew Time Per Run	Total Crew Time Per Mission
Resting and bicycle ergometry	1 hr 13 min	43 min	1 hr 56 min	17 hr 24 min
Unsuited maintenance task	81 min	48 min	2 hr 48 min	19 hr 21 min
Suited maintenance task	120 min	70 min	3 hr 10 min	28 hr 30 min
			Total	65 hr 15 min

Table 1-12. Metabolic Activity Data Measurement Requirements

Measurement	Units	Range	Average	% Tolerance	Channels Required
Respiration Rate	Breaths/minute	8 - 40	12	±3	1
Heart Rate	Beats/minute	40 - 180	70	±3	1
Body Temperature	°K °F	308 - 314 (95 - 105)	310	±0.1	1
Blood Pressure	mm Hg.	300/150 - 100/60	120/80	±3	1
Ergometer Output	watts	50 - 300		±3	1
Ergometer Speed	rpm	40 - 90	60 - 80	±3	1
Metabolic Device					6
Voice, Identification, Time					1

1.4.6.2 Body Mass Measurement

1.4.6.3 Ventilatory Mechanics

1.4.6.4 Blood and Ventilatory Gas Exchange

1.4.7 HEMATOLOGIC FUNCTION

1.4.7.1 Blood Volume and Red Cell Life Span

1.4.7.1.1 Scientific or Technical Objectives. To document changes in red cell mass, red cell survival and plasma volumes occurring during space flight. Documentation and explanation of these changes are necessary before man can be committed to longer duration flights with safety. While this experiment, as presently conceived, is done only pre- and postflight, it can be altered with minimal effort for inclusion in an in-flight program.

1.4.7.1.2 Description. Red cell mass and plasma volume measurements will be performed pre- and postflight to monitor inflight blood volume changes. Tests will be repeated at a later time to see if the body fluid compartments recover to preflight values with time. The disappearance of the Cr^{51} injected for the red cell mass will be monitored to gain information about red cell destruction rates. C^{14} glycine survivals will be used to determine if red cell destruction is age-dependent. Radioisotope counting over the surface of the liver and spleen for Cr^{51} radioactivity will give information about red cell equestration. Red cell production rate will be studied by Fe^{59} turnover studies.

In addition to the studies of red cell production, distribution and destruction studies of plasma volume change will be made. Plasma volume utilizing radioiodinated human serum albumin (I^{125}) will be performed simultaneously with the red cell masses. In this way, changes in total blood volume and total body to peripheral venous hematocrit ratio can be assessed.

With proper use of albumin tracers and external counting techniques, it will be possible to document shifts in plasma volume during orthostatic intolerance studies. Shifts of vascular albumin to the extravascular space will be followed by changes in I^{125} specific activity ($\mu C/g$). Other radioactive protein tags will be used to separate extravascular from intravascular albumin and globulins.

1.4.7.1.3 Observation/Measurement Program. The following preflight schedule should be representative of the measurement program for this experiment. Fifteen days prior to launch (F-15) 100 μC of C^{14} labeled glycine will be injected into a superficial arm vein. No further testing will be done until F-10, at which time a Cr^{51} red cell mass, I^{125} plasma volume, and plasma iron will be determined. This will be accomplished by drawing 35 ml of blood (10 ml for a plasma iron, 10 ml for a background sample, and 15 ml for tagging) and by injecting 2.5 μC of radioiodinated human serum albumin for the plasma volume. The 15-ml aliquot of blood is incubated for 10 minutes in ACD solution with 100 μC of $Cr^{51}Na$ chromate. After terminating the incubation by addition of 0.3 ml of USP ascorbic acid, a 10-ml aliquot of the incubate is transfused back into the autogenous donor. After a fifteen minute mixing time, an

8-ml blood sample is withdrawn. This entire procedure shall be carried out following a recumbent interval for achievement of a baseline state and the astronauts will remain recumbent throughout the test. Samples will be taken for the establishment of the Cr^{51} and C^{14} red cell survival curve on F-8 and F-3.

On F-8 and F-3 a spleen-to-liver ratio will also be determined by counting for five minutes over the respective areas with a scintillation detector.

During the postflight interval the same procedure will be done, only the timing is somewhat different.

All samples will be counted in duplicate and adequate counting times will be observed to achieve statistical significance. The integrated whole-body radiation dose per astronaut for the entire series would not exceed 780 mrad.

1.4.7.1.4 Interface, Support and Performance Requirements. No special facilities are needed other than the laboratories and equipment which exist at MSC and KSC. Arrangements must be made by MSC to send existing portable lab boxes, probe stands, probes, rate meters and associated electronic gear to the Cape Kennedy MSO building and to the recovery site.

No special data support facilities are necessary. All needed equipment will be brought as a portable laboratory which requires six feet of bench space and two 115 Vac standard outlets. Dry ice is required for sample shipment.

AEC approval of these studies is necessary and will be initiated by the principal investigator.

1.4.7.1.5 Potential Role of Man. No special crew skills are required. A comprehensive briefing of all crew members will be required prior to the start of these studies. Approximately 100 min. preflight and 60 min. postflight are required for each astronaut.

All blood drawing, on-site preparations, and radioactive counting of the crew will be done by a physician trained in the techniques involved.

1.4.7.1.6 Available Background Data

a. Experiment Implementation Plan, M113, Blood Volume & Red Cell Life Span, NASA DB-64-68-M113, May, 1968.

b. Fischer, C. F., Johnson, P. C. and Berry, C. A., Red Blood Cell Mass and Plasma Volume Changes in Manned Space Flight, J.A.M.A. 200:579, 1967.

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8-ml blood sample is withdrawn. This entire procedure shall be carried out following a recumbent interval for achievement of a baseline state and the astronauts will remain recumbent throughout the test. Samples will be taken for the establishment of the Cr^{51} and C^{14} red cell survival curve on F-8 and F-3.

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All blood drawing, on-site preparations, and radioactive counting of the crew will be done by a physician trained in the techniques involved.

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b. Fischer, C. F., Johnson, P. C. and Berry, C. A., Red Blood Cell Mass and Plasma Volume Changes in Manned Space Flight, J.A.M.A. 200:579, 1967.

1.4.7.2 Red Blood Cell Metabolism

1.4.7.3 Special Hematologic Effects

1.4.7.4 Blood Coagulation

1.4.8 MICROBIOLOGY AND IMMUNOLOGIC FUNCTION

1.4.8.1 Man's Immunity in vitro Aspects

1.4.8.1.1 Scientific or Technical Objectives. The objectives of this experiment include assay of humoral and cellular immunity, as reflected by the plasma concentration of the major immunoglobular classes, α2M-globulins, transferrin, and β1A-C'3 component; the functions of blood lymphocytes, and assay of selected coagulation factors. This program is deemed essential for the commitment of man to extended space flights. While this experiment, as presently conceived, is done only pre- and post-flight, it can be altered with minimal effort for inclusion in an inflight program.

1.4.8.1.2 Description. The possible influence of the unusual environment to which the astronauts are exposed in outer space upon the humoral and cellular immune mechanism and upon the coagulation mechanism will be investigated. Significant alterations of these functions may produce prejudicial effects upon normal physiological processes. In particular, alterations of immunologic functions may result in increased susceptibility to infections and conceivably can induce onset of autoimmune diseases. Alterations of hemodynamic aspects may produce thromboembolic and/or hemorrhagic disorders.

Studies being proposed are designed to determine the effects of space travel upon the humoral and cellular facets of human immune phenomena and coagulation mechanism, and are more specifically planned to detect quantitative and/or qualitative changes in the immunoglobins and lymphocyte functions, as well as the fibrinonolytic system.

The experimental procedure will be to analyze samples of serum and urine taken from the crew. The contractors have developed and assembled the laboratory facilities, equipment, and instruments necessary for processing samples. They will furnish all personnel, equipment and material required for the prosecution of protocol. The contractors will provide interpretations of all data derived from this experiment.

1.4.8.1.3 Observation/Measurement Program. An experiment schedule will vary with the nature of the missions. For instance, for a ground-based study, the following study would be considered practical and desirable:

a. Three baseline studies (pre-stress state) at F-21 days, F-7 days and F-3 days.

b. Two to five examinations during the test (stress state), if possible.

c. Three examinations after completion of chamber tests (post-stress state), as soon as possible after termination of the test, at F + 6 days, and F + 21 days.

Studies to be performed on the flight should preferably follow a similar pattern. Each crew member will spend approximately five minutes for each sample. The procedure for blood samples is coordinated with all other blood sample requirements of other experiments. Table 1-13 lists measurements to be made in this experiment.

1.4.8.1.4 Interface, Support and Performance Requirements. The venous blood samples obtained at the test sites will be processed on site immediately. Necessary portable equipment will be supplied by examiners. Freshly drawn blood is placed in a self-contained incubator at 310°K (37°C) for protein and lymphocyte studies, and aliquots are placed in dry ice for coagulation studies. The laboratory required includes that needed for serum and tissue protein analysis and lymphocyte studies, electrophoresis, chromatography, radiography and serological assays.

1.4.8.1.5 Potential Role of Man. No astronaut training is required. The task for each crew member is limited to obtaining venous blood and urine samples. A highly trained lab technician is needed for the sample assay.

1.4.8.1.6 Available Background Data

a. Governing Protocol, M110, Hematology and Immunology, NASA DB-83-68-M110, June 1968.

b. Experiment Implementation Plan, M-112, Man's Immunity - in vitro Aspects, NASA DB-86-68-M112, July 1968.

1.4.8.2 Cytogenic Studies of Blood

1.4.8.3 Microbial Profiles of Crew Members

1.4.9 ENDOCRINE FUNCTION

1.4.9.1 Endocrine Assays

1.4.9.1.1 Scientific or Technical Objectives. To determine the effect of space flight stresses, both simulated and actual, on the response of the endocrine system, specifically the pituitary, thyroid, parathyroid, adrenal and neurohumoral functions.

1.4.9.1.2 Description. Endocrine assays will be performed preflight, inflight, and postflight to monitor the hormonal responses to environmental stressors. The assays will entail the sampling and analysis of: various urinary hormones including 17-hydroxy/steroids, aldosterone, 17 ketosteroids, 17 hydroxy corticosteroids,

Table 1-13. Man's Immunity Measurements

Measurement	Normal Range (2 σ)	Equipment or Technique	Sample Size
A. Humoral Immunity			
1. Total Plasma Proteins	6.0 - 8.5 g%	Goldberg temperature-compensated refractometer.	0.2 ml plasma
2. Plasma Globulins		Electrophoresis using Spinco microzone cellulose-acetate technique.	
albumin	3.35 - 5.17 g%		
α1-globulin	0.16 - 0.36 g%		
α2-globulin	0.45 - 1.05 g%		
β-globulin	0.55 - 1.04 g%		
γ-globulin	0.62 - 1.52 g%		
3. Plasma Immunoglobins		Immunoelectrophoresis using an agar-gel microtechnique.	8 μl per protein determination
IgG/γ G-globulin	700-1700 mg%		
IgA/γ A-globulin	70-350 mg%		
IgM/γ M-globulin	70-120 mg%		
α2M-globulin	130-370 mg%		
Transferrin	200-440 mg%		
β1A-C'3 Component	40-140 mg%		
4. Plasma Enzyme		Prochop turbitimetry	
Muramidose (lysozyme)	≥6 μg/ml		
B. Cellular Immunity			
1. Lymphocytes		Nylon-recticulum column technique	15 ml of heparinized venous blood
C. Coagulation Studies		Fibrinolytic activation and inhibition	7.5 ml citrated plasma 5.0 ml urine

catecholamines, parathyroid hormones, and serotonin; blood PBI, ACTH, ISH, and electrolytes; respiratory gases, and skin and core temperatures for metabolic loads; and selective histological examination of various tissues. Adequate assessment of the various hormone functions should lead to the quantification of the effects of prolonged space flight, and the eventual development of remedial processes to prevent untoward deterioration of stress-defense mechanisms. Of critical importance will be the assessment of temporal and adaptive changes.

1.4.9.1.3 Observation/Measurement Program. The program will be carried out in three phrases:

a. Preflight Ground Tests. Quantitative determinations of the above measurements will be made by extensive sampling on each crew member prior to flight. This will establish the baseline on each individual who will serve as his own control for the stresses experienced during flight.

b. Flight Tests. Sampling and quantitative determinations will be made on a regular basis (10-14 days) during the space flight. Depending upon the onboard analytical capability, samples may be preserved and returned to Earth for confirmatory analysis. Additional samples will be taken as indicated and as available after particularly stressful events or tasks, as well as after specific programmed exercises and activities.

c. Post Flight. Similar quantitative analyses will be performed for some time after the flight to determine the long-term or permanent effects, if any, of stress on the crew members, as well as to ascertain the readaption responses.

Representative types of measurement equipment/techniques will include: all crew members as subjects, the biochemical-biophysical analysis unit, the biomedical behavioral unit including ergometer and the stress study analysis task, and various environmental monitors.

1.4.9.1.4 Interface, Support and Performance Requirements

a. Operational Constraints. Identification and quantitation, if possible, of stressful situations (emergencies, long-term isolation, metabolic imbalance, etc.) will be critical to the experiment and the interpretation of the results. Acceleration during liftoff and re-entry might be critical. Altitude, inclination and pointing should not be critical. Caloric intake radiation exposure and thermal imbalances will be critical particularly to the responses of the body's temperature regulation mechanisms and the gonadal histopathology. Ability to take samples during or just following stressful situations could be critical.

b. Data. Periodic dumps will be required, probably once or twice a week. Other measures of physical well-being would replace the need for continuous monitoring

for this experiment. Special data is dependent upon development of unplanned stressful situations and clinical status of the crew. Postflight specimen return will be required.

c. Spacecraft Support

1. Power - 220 watts.

2. Volume - 0.3 m^3 (10 ft^3).

3. Weight - 70 kg (150 lb).

4. Data - Manual log, 1000 bits/sample.

d. Crew Support. Sampling for this experiment will be included in urine and blood samples taken for other purposes. Sampling time is 1/4 hour (included in sampling for other purposes). Sample preservation is included in sampling for other purposes. Sampling for this experiment should be correlated with samples required for other experiments or clinical needs. Sampling occurs every four days for the extent of mission. Clinical experience is required for the relationship of endocrinology to overall homeostasis. Biochemistry technician capability along with clinical training in sampling is required.

1.4.9.1.5 Potential Role of Man. This experiment will: (a) utilize the crew members as test subjects, although this could be augmented by combining the assays required with other proposed animal experiment; (b) utilize man to take samples and preserve them as serendipitous stressful events occur; and (c) allow for performance of onboard in-flight measurements when the clinical system is available with its attendant physician.

1.4.9.1.6 Available Background Data:

a. Clinical

1. Influence disposition of foodstuffs, electrolytes, and water in the body.

2. Homeostatic influences.

b. Space Flights

1. Observations from past flights are too sketchy to present precise picture of the endocrine system response to stresses.

2. Minimal information gained thus far indicate: (a) decreased endocrine activity during flight, and (b) increased activity after re-entry.

1.4.9.2 Thermoregulation

1.4.9.3 Gonad Histopathology

1.4.10 CLINICAL/THERAPEUTIC FUNCTION

1.4.10.1 Exercise Conditioning

1.4.10.1.1 Scientific or Technical Objectives. Experiment objectives are:

a. To provide countermeasures to assure maintenance of the physiological integrity of the musculoskeletal system under prolonged exposure to weightlessness.

b. To define and develop therapeutic procedures to maintain the health and well-being of the crew and to determine the minimum amount of exercise capable of counteracting zero-g conditioning.

1.4.10.1.2 Description. Many of the compensatory mechanisms of the body associated with the maintenance of physiological homeostasis under the gravitational stress of 1 g are the same as those that function during an exercise stress. It has been suggested that exercise may be substituted for gravity as a stimulus for the compensatory reflexes during weightless spaceflight to prevent physiological deconditioning.

Three crew subjects will participate in the exercise conditioning regimen. An ergometer equipped with a hysteresis brake will be used so that the set workload will be independent of pedal speed. A workload that will produce a steady-state heart rate of approximately 150 beats per minute will be determined for each subject before flight. Exercise for each participating subject will occur twice daily. Each exercise period will be of 15-minute duration. Heart rate will be measured by a cardiotachometric analysis of the electrocardiogram.

This suggested exercise program may be modified in intensity, duration or frequency because of preceding ground-based or inflight research.

1.4.10.1.3 Observation/Measurement Program. Exercise will be performed daily throughout the duration of the crew cycle, consisting of two 15-minute periods by each of three subjects. Ergometer workload will be preset and heart rate will be monitored throughout the exercise.

Ergometer workload is here defined as the workload imposed by the bicycle ergometer and not the metabolic rate of the subject. It is expressed in watts and can be preset (0-300 watts) on the ergometer, which will vary resistance in relation to pedal speed or heart rate to maintain the desired workload.

Heart rate will be derived by detecting the time interval between successive R waves on the ECG. The heart rate, ergometer workload, and ergometer RPM will be continuously displayed and stored. Heart rate can be displayed selectably to beat-by-beat, 10-sec, 30-sec, 1-min, or 5-min average. Table 1-14 lists the equipment needed for this experiment. Electrode paste is the only expendable.

Table 1-14. Exercise Conditioning Equipment Summary

Item	Weight kg (lb)	Volume m^3 (ft^3)	Power W	Available Model
Bicycle Ergometer	23 (50)	0.1 (4) stored; 0.6 (20) operating, including subject	10	Skylab M171 Model
ECG/VCG (lead vest + pre-amp)	2 (4)	0.01 (0.3)	1	Skylab M093 Model
Cardiotachometer	1.5 (3)	0.005 (0.2)	5	Under Development
Timer	2.3 (5)	0.01 (0.3)	1	Skylab Exp. Support System
TOTALS	28 (62)	0.6 (21)	17	

Approximately 20 min/measurement day and 8 min/subject are required for setup and stowage of the experiment. This is in addition to the 30 minutes of exercise per subject each day.

1.4.10.1.4 Interface, Support and Performance Requirements. The exercise program should commence as soon as possible after launch to prevent any significant deconditioning from occurring prior to the start of the program. It should not be interrupted for more than one day in succession and not more than twice during any 7-day period. Daily scheduling is not critical.

The data output rate is 40 bits/min. for heart rate and 80 bits/min. for ergometer workload for a total of 120 bits/min.

Weight of the experiment equipment is 30 kg (62 lb) and operational volume is 0.6 m^3 (21 ft^3). Power requirements are 17 watts for approximately 90 minutes/day.

1.4.10.1.5 Potential Role of Man. Three astronauts will participate in the exercise conditioning program and will serve as the conditioned subjects for concurrent experiment. Prelaunch training will consist of familiarization with the exercise equipment and procedures.

1.4.10.1.6 Available Background Data. Experiment 1-124, Requirements Study for a Biotechnology Laboratory for Manned Earth-Orbiting Mission, Phase I, Volumes I and II, MDC G0620, 1970.

1.4.10.2 Wound Healing

1.4.11 ENVIRONMENTAL FACTORS

1.4.11.1 Airborne and Surface Contamination

1.4.11.1.1 Scientific or Technical Objectives. To determine a) the occurrence of changes in the types of microorganisms consisistently found to be contaminants of spacecraft air and surfaces, and b) whether or not pathogenic or potentially pathogenic species become the predominant contaminants.

1.4.11.1.2 Description. Weekly air samples will be taken with a Reynier Air Sampler or equivalent, and Rodac plates will be used to sample selected surfaces throughout the spacecraft. The agar plates (Reynier and Rodac) will be incubated 48 hours at 310°K (37°C), the colonies counted, and morphologically different colonies picked and streaked in nutrient agar plates for isolation. After 24 hours' incubation at 310°K, the isolated colonies will be picked, samples gram stained, and samples transferred to nutrient broth as well as to appropriate differential and/or selective media. Appropriate biochemical tests will be utilized to identify the microorganisms to genus and species.

1.4.11.1.3 Observation/Measurement Program. Air and surface samples will be taken weekly throughout the mission. For the air sample, a crew member places a Reynier plate (layered with nutrient agar) into the Reynier Sampler and initiates the vacuum pump which draws air through a slit onto the surface of the agar, impinging microorganisms at a specified rate. The Reynier plate rotates slowly so that the entire surface is exposed to the slit over a one-hour period. The crewman then terminates the sampling operation by turning off the vacuum source, removing the agar plate, labeling it, and placing it in the 310°K incubator. Twenty-four hours later, the plate is analyzed and organisms counted. The time required for setup and stowage is 10 minutes per week per sampler.

The microbial surface sampling consists of a crew member pressing agar surfaces of Rodac plates to the designated surface to be sampled, placing a top onto the plate, labeling as to time and site, and putting the plates into the 310°K incubator. Operation is repeated using a Rodac plate for each surface to be sampled. The time required for plate collection is two minutes per week per surface.

Table 1-15 details the equipment needed for this experiment. Necessary expendable supplies are: culture tubes, plates, media, sampling swabs, Rodac plates, distilled water, and miscellaneous chemical reagents. Most of this equipment is further detailed in FPE 4, Section 4.2.2.

1.4.11.1.4 Interface, Support and Performance Requirements. Sampling should begin within one week after launch to establish early baseline for potential changes thereafter. Schedule variability is undesirable, but will not affect the data significantly unless several sampling periods are omitted.

Table 1-15. Airborne and Surface Contamination Equipment Summary

Item	Weight kg (lb)	Volume m^3 (ft^3)	Power W	Available Model
Autoclave	9 (20)	0.03 (1)	1000	Castle's Portable Electric Speedclave
Colony Counter	4.5 (10)	0.03 (1)	20	
Media Preparation Containers	0.5 (1)	0.015 (0.5)	None	
Microbial Air Sampler	3 (6.5)	0.001 (0.03)	--	Scientific Product's TDL Particle Slit Samples (Reynier)
Timer	2 (4.5)	0.01 (0.3)	1	
High Temperature Sterilizer	4.5 (10)	0.015 (0.5)	200	
Incubator	4.5 (10)	0.02 (0.7)	40	See Section 4.2.2
TOTAL	28 (62)	0.12 (4.0)	1260	

There is a need for resupply of expendables - sample plates, swabs, media, etc. There are no data requirements other than the keeping of written records.

1.4.11.1.5 Potential Role of Man. Two microbiologists or microbiology technicians are required for identification of air and surface contaminants by classical microbiological methods. It is estimated that these procedures will require 5 hr/wk by each technician.

1.4.11.1.6 Available Background Data. Experiment 1-129, Requirements Study for a Biotechnology Laboratory for Manned Earth-Orbiting Mission, Phase II, Volumes I and II, MDC G0620, 1970.

1.4.11.2 Radiation Effects

1.5 FPE INTERFACE, SUPPORT AND PERFORMANCE REQUIREMENTS

The summary data in Table 1-16 represents, in the best judgment of NASA scientists, the overall facility and experimental requirements to accomplish a realistic experimental program, and is based on some projection of the state-of-the-art. The

Table 1-16. FPE Summary Data

			Notes
Weight, kg (lb)	3010 (6675)		1
Volume, m^3 (ft^3)	44 (1560)		1
Power, watts	3550		2
Crew Skills	1, 2, 3, 4, 12, 13, 22		
Data Rate, bps	930		2
Logistics up, 30-day average, kg (lb)	40 (88)		3
Logistics down, kg (lb)	30 (68)	1st two years	4
	36 (81)	3rd year on	5
Pointing & Stabilization	NA		
Orbit Altitude & Inclination	NA		
Unique Environment Requirements	Station nominal environment. No mission maneuvering during experiments.		

Note 1: CORE units + FPE units + two logistic cycles of expendables. Radiobiology unit not included.

Note 2: 40% of CORE units total + 25% of FPE units total = normal load.

Note 3: 110% of expendables for 30 days + 1% of FPE equipment.

Note 4: 75% of logistics up.

Note 5: 90% of logistics up.

rationale for selection of the summary parameters is in some instances arbitrary but has as a basis the total NASA experience and knowledge gained from prior flight and experiment definition and integration program. The basis for each data entry is given in the notes.

1.6 POTENTIAL MODE OF OPERATION

The Medical Research Facility is expected to become an integral part of the Space Station or Space Base program as a means of 1) monitoring the astronaut or crewman welfare and 2) performing basic research on the effects of the space environment on

man. The experiment program duration is open-ended. The first two 90-day cycles of testing will establish basic requirements for future testing. Testing will not be performed during periods of transient vibration and acceleration. Certain experiments impose environmental and crew skills constraints on scheduling.

Considering Flight Mode A, limited on-orbit stay time as with Space Shuttle, all experiments can be accommodated but most will be decreased in value as indices for predicting long term phenomena. With Flight Mode B, extended on-orbit stay time, unmanned, with periodic revisits by Shuttle, none of the experiments can be satisfactorily accommodated because man's presence is a requirement. Flight Mode C, extended on-orbit stay time with Space Station, is preferred for all experiments because determining the long-duration effects of the space-flight environment on man is a specific objective of this FPE.

The experiment program anticipated for the Medical Research Facility might be called cautious because it seeks to carefully determine the effects of the space environment before proceeding with further experimentation or longer duration flights. Therefore it might be established early in the flight that certain measurements or experiments are not necessary. The associated equipment will be returned to Earth and new or updated experiments and equipment added for further investigations.

1.7 ROLE OF MAN

The role of man as both operator and subject is shown in Table 1-17.

1.8 SCHEDULES

To be determined.

1.9 PRELAUNCH SUPPORT REQUIREMENTS AND GSE

There are no prelaunch support requirements for this FPE except for supply of laboratory consumables. There will be requirements for resupply and return of refrigerated samples and specimens. Rapid distribution of these samples to the respective principal investigators is imperative.

1.10 SAFETY ANALYSIS

General laboratory safety procedures should suffice for the operation of this FPE. Areas of potential hazards would be: electrical shock in electrophysiological studies (ECG, EEG, etc.), handling of noxious or poisonous reagents in the chemistry laboratory, and radiation dangers in the use of radioisotope materials.

Table 1-17. Crew Support Requirements

FPE FUNCTION	CREW TASK			CREW		CREW CONSTRAINTS
	TASK DESCRIPTION	FREQUENCY	DURATION (EACH OCCURRENCE)	NUMBER	SKILL	
Equipment Preparations	Remove launch supports, deploy, unstow and/or install equipment, transport expendables/equipment brought up with initial crew to Biomed area and stow, and/or service equipments as required	Once	10 hours (20 manhours)	Both	Electromed Tech-Oper Med Tech	
Initialization and Verification	Check out experiment equipment operations, support equipment operations, lab analysis equipment and IMS programming and monitoring functions	Once	14 hours (28 manhours)	Both	Med Doctor Med Tech	
Experiment Activation	Instrument subject; prepare equipment, configure measurement device, activate analysis support equip and/or initiate measurement sequence	Initial measurement period (90 days) 16 times per day	Operator, 12 to 30 min; total each day, 6.2 hours	1	Med Doctor or Med Tech (Operator)	Total testing time (Activation + Operation) for all six subjects is 21.4 manhours per day. Two-shift use of equipment is therefore required for the Med Doctor and Med Tech to accommodate program. Experiment Operations must immediately follow activation tasks
			Subjects, 0 to 30 min. Total each day for all six subjects, 5.0 hours	1	Any (6 subjects)	
		Second measurement period (90 days) eight times per day	Operator, 12 to 30 min; total each day, 3.1 hours	1	Med Doctor or Med Tech (Operator)	Experiment Operations must immediately follow activation tasks
			Subject, 0 to 30 min. Total each day for all six subjects, 2.5 hours	1	Any (6 subjects)	
		Subsequent measurement period (crew stay times in excess of 90 days) 24 times per week	Operator, 12 to 30 min. Total each week, 9.2 hours	1	Med Doctor or Med Tech (Operator)	Same as above
			Subject, 0 to 30 min. Total each week for 3 (assumed) subjects, 7.5 hours	1	Any (3 subjects)	
Experiment Operations	Perform test on primary or supplementary experiment equipment; monitor/control experiment procedures; acquire subjective data or samples or specimens; as required, monitor physical status of test subject	Initial period (90 days) 16 times per day	Operator, 6 to 30 min. Total each day, 7.2 hours	1	Med Doctor or Med Tech (Operator)	See entry for "Experiment Activation", initial period
			Subjects, 6 to 90 min. Total each day for all six subjects, 14.2 hours	1	Any (6 subjects)	
		Second period (90 days) 8 times per day	Operator, 6 to 30 min. Total each day, 3.6 hours	1	Med Doctor or Med Tech (Operator)	Must immediately follow activation tasks
			Subjects, 6 to 90 min. Total each day for all six subjects, 7.1 hours	1	Any (6 subjects)	
		Subsequent periods (crew stay times in excess of 90 days) 24 times per week	Operator, 6 to 30 min. Total each week, 10 hours	1	Med Doctor or Med Tech (Operator)	Same as above
			Subjects, 6 to 90 min. Total each week for 3 (assumed) subjects, 21.3 hours	1	Any (3 subjects)	

Table 1-17. Crew Support Requirements (Continued)

FPE FUNCTION	CREW TASK			CREW		CREW CONSTRAINTS
	TASK DESCRIPTION	FREQUENCY	DURATION (EACH OCCURRENCE)	NUMBER	SKILL	
Experimental Data Evaluation	Perform lab analyses; review, screen, collate, and/or analyze data; review results with ground personnel; provide planning/modification as required	Daily for 90-day period	Initial period, 11 hours	1	Med Doctor, Med Tech and Bio Lab Tech	Scheduled ad lib. Requires three crew members to meet total daily work load for activation, Ops and Data evaluation (24.4 hours). Use of a Lab Tech to support lab analyses and screen selective Biomed data is recommended
		Weekly	Second period, 5.5 hours	1	Med Doctor or Med Tech	Scheduled ad lib by either crew skill
		Weekly	Subsequent periods, 16.5 hours	1	Med Doctor or Med Tech	
Experiment Deactivation	Remove subject instrumentation, stow equipment, complete operational log	Initial measurement period (90 days), 2/day	5 minutes (30 manminutes)	6	Any (each subject)	
		Second measurement period (90 days), 1/day	5 minutes (30 manminutes)	6	Same as above	
		Subsequent measurement periods, 8/wk	5 minutes (15 manminutes)	3	Same as above	
Refurbishing	Replace lab analysis materials, service equipment and modify/upgrade equipment as required (including time to reinitialize and verify open status)	Subsequent to each testing period	10 hours (20 manhours)	Both	Electromech Tech - Oper Med Tech	Concurrent with logistics resupply schedule and crew recycling
Package and Return	Prepare physical data, specimens, samples and records for return to ground	Every two months (assuming a 60-day logistic resupply cycle) through duration of FPE	4 hours (8 manhours)	Both	Med Doctor Med Tech	
Corrective Maintenance	Provide diagnostic support, remove and replace faulty units, repair as required, and verify corrective action	As required	2-10 hours (2-20 manhours)	1 - 2	May include Electromech Tech - Oper Med Tech	No. and type of crew members required contingent upon nature of malfunction

1.11 AVAILABLE BACKGROUND DATA

a. Requirements Study for a Biotechnology Laboratory for Manned Earth-Orbiting Missions; Volume I, CR-1408, Volume II, CR-1409; McDonnell Douglas Astronautics Co., February 1969.

b. Candidate Experiment Program for Manned Space Stations ("Blue Book"), OMSF, NASA, 14 November 1969.

c. Requirements Study for a Biotechnology Laboratory for Manned Earth-Orbiting Missions - Phase II, Volume 1, MDC GO620, McDonnell Douglas Astronautics Co., July 1970.

d. Space Station Program, Experiment Data Book, EL-103, Revision C, Vol. I, General Electric Co., June 1970.

e. IMBLMS Phase B4, Statement of Work, Final Project Definition, March 1970.

f. Candidate Experiment Program for Manned Space Stations ("Blue Book"), OMSF, NASA, June 1970.

VOLUME VIII

SECTION 2

VERTEBRATE RESEARCH FACILITY

SECTION 2

VERTEBRATE RESEARCH FACILITY

2.1 GOALS AND OBJECTIVES

This FPE is to define the laboratory support and operational requirements for a vertebrate research facility which, with the CORE, will permit a broad spectrum of specific and general experimentation in pursuit of the goals and objectives discussed under the Space Biology section of the Life Sciences Introduction. Broad objectives are:

a. To determine the effects on vertebrates of space flight, and space environmental factors on:

 1. General physiological function.
 2. Nutrition and nutritional balance.
 3. Neuromuscular function.
 4. Behavior and performance.
 5. Reproduction, growth and development.
 6. Aging and longevity.

b. To assess the extent of the effects precipitated by individual environmental factors and by two or more factors in combination.

c. To apply the results of these determinations and assessments to the solution of problems related to the extension of manned space flight capabilities as well as to biological and medical problems on Earth.

Details of the pursuit of these objectives are presented in Section 2.4.

2.2 PHYSICAL DESCRIPTION

This facility will share all of the Vertebrate Holding and rearing elements, the Bioresearch Centrifuge, Radiobiology unit, Specimen Return unit, and CORE with the Medical Research Facility and other Life Sciences FPE's. The facility concept is illustrated in Figure 2-1. The animal holding facilities should provide for four primates, 256 rats and/or 256 mice, or the equivalent in intermediate sized animals such as marmots.

These facilities are not "all-or-none" and a certain lesser capability is acceptable for selected experiments. It is anticipated that certain missions will in fact be

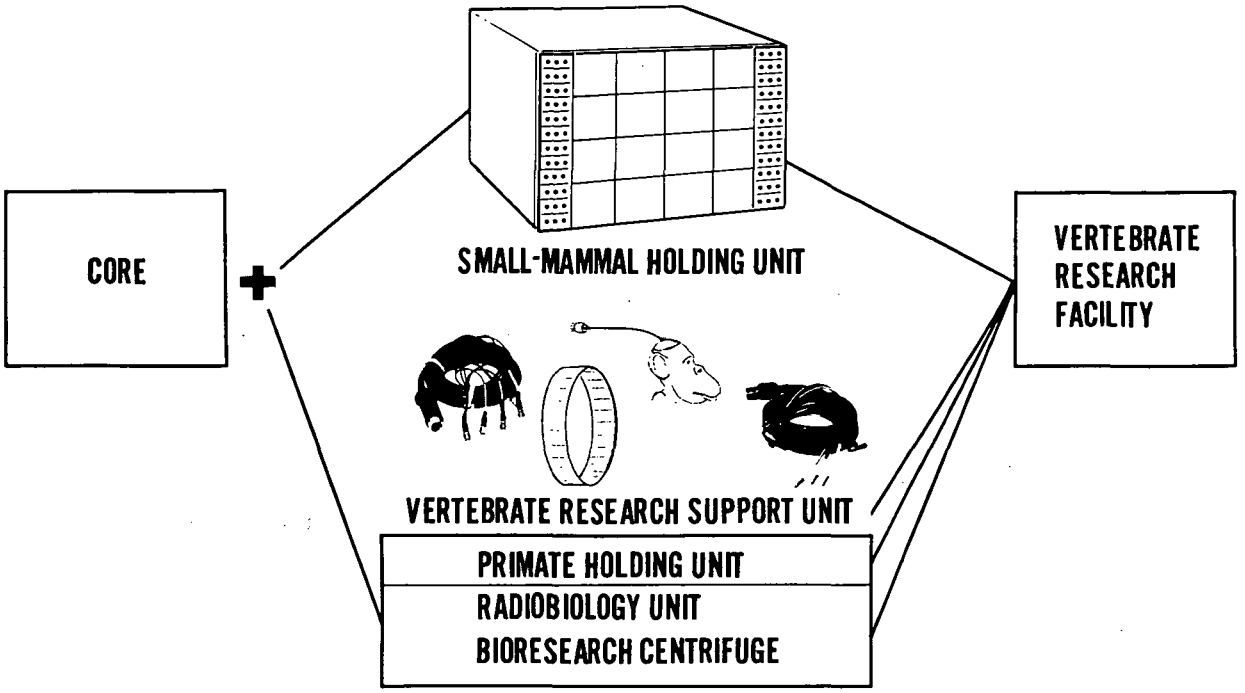


Figure 2-1. Life Sciences Vertebrate Research Facility

limited in the amount and scope of experimental payloads as well as in crew size and flight time. Therefore, scheduling and operational planning will necessarily be dependent upon available technology, mission parameters, and urgency for specific information.

Such a facility provides holding and rearing accommodations as well as research instrumentation for a wide variety of vertebrates. The rearing accommodations will permit establishing a weightlessness-adapted strain of animals (rats and/or mice) considered essential in studying adaptive processes.

When present the Bioresearch Centrifuge, being a growth equipment unit, impacts many other equipment units within Life Sciences biology section. Consequently, engineering data is provided for a lab-only concept and for a lab-plus-centrifuge concept. If no centrifuge is planned, all lab-only values are appropriate. If a centrifuge associated with the bioresearch lab is planned at any time, the volumes, power and data values for the lab plus centrifuge must be used and the lab will operate at approximately 60% of the analytical capacity until the centrifuge is available.

2.2.1 VERTEBRATE RESEARCH SUPPORT UNIT

2.2.1.1 Functional Capability. Functional capabilities described here are those required specifically for vertebrate research. Many transducers listed are functionally identical to other FPE requirements; however, the physical configuration is specific to this FPE. Experiment hardware taken into space for a specific experiment will remain in space as part of this equipment unit. Therefore, a large contingency storage must be planned into this unit. Typical capabilities are:

a. ECG, EEG, EMG, Thermal Measurements

b. Trace Gas Measurements, Organism Activity

c. Ergometry, Camera Systems

d. Vertebrate Restraint

e. Special Holding Systems

f. Behavioral Task Boards

Table 2-1 lists equipment for this unit, and Table 2-2 is the equipment unit summary.

2.2.2 PRIMATE HOLDING UNIT

2.2.2.1 Functional Capability. The primate holding units are 1.5 m (4.92 ft) diam. spheres with a 1 m (3.3 ft) hatch. They are designed to hold chimpanzees or any primate of 48 kg (105 lb) or less. If primates are not part of a mission, these spheres provide excellent holding units in which to study smaller specimens in a free-roaming status. They are flight chambers for invertebrate and avian flight dynamics studies. They can be used for sterile storage or toxic material storage. Most important, the spheres provide to future investigations a large experiment volume for experimentation which cannot be confined to cage-rack dimensions.

2.2.2.2 Specifications

a. Number of Spheres: 4 in Main Lab and 2 in Centrifuge

b. Environmental Control/Life Support

1.	O_2, liters/day/chimpanzee		456
2.	O_2, liters/day/Macaque		80
3.	Heat output, MJ (kcal)/day/chimpanzee	7.54	(1800)

Table 2-1. Vertebrate Research Support Unit Equipment List

Name	Performance Characteristics	Power W	Weight kg(lb)	Volume $m^3(ft^3)$	Other or Remarks
Exerciser/ Ergometer (Primate)		0	2(4.4)	0.006(0.21)	
Primate Calorimetry Module	Measures O_2, CO_2, food intake, urine, feces and activity. Volume includes living quarters; unit includes urine analyzer, feces analyzer, urine and feces storage, and automated hemodynamic subsystem. Can be disassembled for storage.	70	40(88)	6.5(230)	
Cabinet, Drawer and Rack Storage System	To store equipment unit inventory plus all new experiment specific hardware.	0	45(99)	1(35)	
Storage Cabinet for Cages	To store rat cages while lab configured for other organisms, etc.	0	45(99)	2(70)	
Transducer Inventory	See experiment requirements. Power is minimal and provided by Data Management system.	0	9(20)	0.06(2.1)	

4. Heat output, MJ (kcal)/day/Macaque 1.47 (350)

5. Atmospheric requirements

pO_2	160 ± 10 mm Hg
pN_2	580 ± 20 mm Hg
pCO_2	< 6 mm Hg
pH_2O	12 ± 3 mm Hg
Temp.	298 ± 2°K (25 ± 2°C)

Table 2-2. Equipment Unit Summary

	Laboratory Only	Laboratory + Centrifuge
OPERATOR SKILL	TBD	
POWER, AC		
average, watts	0	
peak, watts	0	
peak duration, hr/day	0	
POWER, DC		
average, watts	390	
peak, watts	390	
peak duration, hr/day	24	
WEIGHT, kg (lb)	143(315)	
ENVELOPE		
volume, m^3 (ft^3)	3(105)	
height, cm (in.)	TBD	
width or diam. cm (in.)	TBD	
depth, cm (in.)	TBD	

6. Trace Contaminants — Space Maximum Allowable Concentration (SMAC) for man

7. Air Velocity — 0.25 ± 0.03 m/sec.

c. Data Requirements - Supplemental data management unit plus a signal conditioner rack and module system at each sphere for 20 channels of specimen data and 10 channels of cage and environmental data.

d. Environmental Control System - Supply from main specimen ECS via standard manifold. Connections to manifold identical to cage racks.

e. Support Equipment - The spheres must be capable of accommodating:

1. Primate exerciser/ergometer.

2. Primate metabolism apparatus.

3. Hemodynamic measurements restraint and system.

Unit equipment is listed in Table 2-3; Table 2-4 is an equipment unit summary.

Table 2-3. Primate Holding Unit Equipment List

Name	Performance Characteristics	Power W	Weight kg(lb)	Volume $m^3(ft^3)$	Remarks
Primate Holding Units	Support primates as described in experiments	25	50(110)	2(70)	
Rack and Module System	To support the primate holding units; to contain the support manifold. Also contains rack for electronic plug-in and electo-mechanical actuators	0	18(40)	0.15(4.8)	
Primate Holding Unit Cage or Liners	To be inserted into sphere to provide the experiment-specific configuration.	0	5(11)	TBD	
Primate Transfer Module	Self-contained LS/EC system for approximately 24 hours. Module is to isolate and restrain the primate during transfer from ground to spacecraft.	0	75(165)	TBD	

2.2.3 SMALL MAMMAL HOLDING UNIT

2.2.3.1 Functional Capability. This equipment unit will hold and experimentally support the following:

	Lab Only	Lab + Centrifuge
Rats, quail, or similar-size specimens:	64	256
Mice, hamsters, or similar-size specimens:	64	256
Marmots, rabbits, or similar-size specimens:	24	70

Table 2-4. Equipment Unit Summary

	Laboratory Only	Laboratory + Centrifuge
OPERATOR SKILL	TBD	TBD
POWER, AC		
average, watts	0	0
peak, watts	0	0
peak duration, hr/day	0	0
POWER, DC		
average, watts	100	150
peak, watts	100	150
peak duration, hr/day	24	24
WEIGHT, kg (lb)	250(550)	370(815)
ENVELOPE		
volume, m^3 (ft^3)	8.5(300)	12.7(450)
height, cm (in.)	4 ea.	6 ea.
width or diam. m (ft)	1.5 (4.92)	1.5 (4.92)
depth, cm (in.)		
DATA		
voice, hr/day	TBD	TBD
TV, B&W, hr/day		
TV, color, hr/day		
analog, MHz	4(0.6 hr/day)	4(1.25 hr/day)
digital, bps	200	350

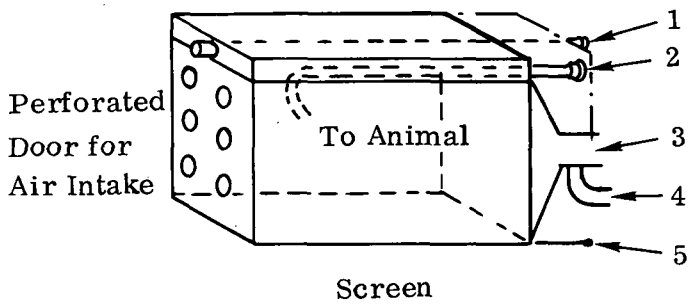
These numbers are based on statistical requirements. For large number statistics, the accepted minimum number is 30; two specimens per group are added as a contingency factor. Therefore, for rats, quail, and mice or hamsters, and two simultaneous experiments of each size organism with four variables (two on the centrifuge and two in zero g), assume groups at 32 animals each. These numbers are for planning of the maximum facility. Appropriate scaling is required for smaller facilities.

It is recognized that smaller numbers can be statistically significant for given hypotheses. In this case, more than two experiments can be conducted simultaneously for one size organism.

2.2.3.2 Description. The specimens require the following:

	Volume, m^3 (in^3)	Data Channels Per Specimen
Rats and quail, ea.	0.007 (427)	5
Mice and hamsters, ea.	0.0017 (104)	2
Marmots, rabbits, ea.	0.025 (1520)	12

The volume includes the specimen cage, cage connections (LSS, water and data plug), manifolds and ducting, and the urine, feces and debris collector. Figure 2-2 is a drawing of a cage concept.



1. Bolt with knurled nut on cage front, screws to back wall
2. Data plug
3. LSS exhaust duct
4. Urine & feces mgmt
5. Stabilizer feet

Figure 2-2. Cage Design Concept

Cage design should allow compact stacking or collapse to minimize storage when not required. Metabolic cages and colony cages will be larger than the single standard cage and require multiples of space and manifold connections. Mice and hamsters require basically the same cage as rats, with dividers accommodating 4 mice in place of 1 rat. Marmots, rabbits and guinea pigs require a cage four times the volume of the rat cage, and utilize one to four manifold connections. Life support to each specimen must be sterile and within toxicological SMAC (Space Maximum Allowable Concentrations).

Recirculation of environmental gas is allowable for small groups of specimens. A maximum number is half of one experiment group or 16 specimens for recirculation.

The following environmental data requirements apply for small animals:

	Range Capability	Typical Experiment Limits
Light	0-1300 lum/m^2 (0-120 ft.-C)	1100 ± 10 lum/m^2 (100±1 ft.-C)
Temperature	278 to 333°K (5-60°C)	298 ± 1°K (25 ± 1°C)
Humidity	10 - 80% rh	50 ± 5%
pO_2	50 - 200 mm Hg	160 ± 5 mm Hg
pN_2	400 - 800 mm Hg	600 ± 10 mm Hg
pCO_2	0 - 40 mm Hg	<5 mm Hg
pNH_3	N/A	0.01 mm Hg
pCO	N/A	0.01 mm Hg

Using the cage rack model, 65 x 65 x 40 cm, (25.6 x 25.6 x 15.7 in) for the lab only, 11 specimen cage containment (cage racks) are required. Lab and centrifuge specimen cage containment requirements are to be determined. Modular electronic chasses for preamplifiers, signal conditioners, and experiment controllers are required of part of the holding unit. Instrumentation power is 28 Vdc. Use most economical power for heat, blowers, etc.

Table 2-5 lists unit equipment. Table 2-6 is a summary of the equipment unit.

2.3 EXPERIMENT REQUIREMENTS SUMMARY

See Tables 2-8, 2-9 and 2-10 within the experiment classes.

2.4 EXPERIMENT PROGRAM

The vertebrate research program is comprised of a group of representative experiment classes, each supported by a group of representative experiments. Within each class the first of the representative experiments is described in detail; other representative experiments are given by title and experiment requirements data only. These selected representative experiments provide details of experiment support requirements and other spacecraft and mission impacts to a level that is ample to characterize the requisite Vertebrate Research Facility. Table 2-7 enumerates the representative experiment classes and experiments that scope the experiment program.

Table 2-5. Small Animal Holding Unit Equipment

Name	Performance Characteristics	Power W	Weight kg(lb)	Volume $m^3(ft^3)$	Other or Remarks
Holding Units	Standard size 65x65x40 cm (25x25x16 in).	50	27(60)	0.16(5.66)	Pwr for lighting, feeding and waste management.
Cage Rack Model	Double size 65x130x40 cm (25x50x16 in).				
Lab Only	To hold cages for mice.				
Lab plus Centrifuge	To hold small primates.				
Standard Cages (Rat)	To hold and support 1 rat or rat-sized animal.	20	1(2)	0.0085(0.3)	All cages must support a host of transducers and provide for waste and debris management. Power required for electromechanical actuators.
Colony Cages (Rat)	To hold and support 1 - 8 adult rats or rat-sized animals.	20	5(11)	0.006(2.12)	All cages must support a host of transducers and provide for waste and debris management. Power required for electromechanical actuators.
Metabolic Cages (Rat)	To hold and support 1 rat or rat-sized animal with waste separation and collection.	20	2(5)	0.014(0.5)	Must support transducers as pO_2, pCO_2, activity, ECG, etc. 32 required
Standard Cages (Rabbit)	To hold and support 1 rabbit or rabbit-sized animal.	20	1(3)	0.035(1.24)	

Table 2-5. Small Animal Holding Unit Equipment (Cont)

Name	Performance Characteristics	Power W	Weight kg(lb)	Volume $m^3(ft^3)$	Other or Remarks
Colony Cages (Rabbit)	To hold 1-4 rabbits or rabbit-size animals.	20	5(12)	0.14(4.95)	
Metabolic Cages (Rabbit)	To hold and support 1 rabbit or rabbit-sized animal with waste separation and collection.	20	3(6.6)	0.060(2.12)	Must support transducers as pO_2, pCO_2, Activity, EEG, ECC, etc.
Rat Cage (Inserts for Mice)	Divides 1 rat cage into 4 mice cages.	0	2.5(5.5)	0.0003(0.01)	
Rack and Manifold System for Holding Inserts	Physical support for holding inserts plus manifold and electrical harness system.	0	90(199)	2(70.5)	Double valves for centrifuge
Aquaria	To hold aquatic organism; must have zero-g gas exchange system.	10	5(11)	0.028(1)	Weight empty
Transport Module	Self-contained LS/EC system to contain and isolate animals during transport from ground to spacecraft.	0	50(110)	TBD	

Table 2-6. Equipment Unit Summary

	Laboratory Only	Laboratory + Centrifuge
OPERATOR SKILL	TBD	TBD
POWER, AC		
average, watts	700	1400
peak, watts	700	1400
peak duration, hr/day	24	24
POWER, DC		
average, watts	0	0
peak, watts	0	0
peak duration, hr/day	0	0
WEIGHT, kg (lb)	470(1040)	940(2080)
ENVELOPE		
volume, m^3 (ft^3)	25(885)	50(1770)
height, cm (in.)	TBD	TBD
width or diam. cm (in.)	TBD	TBD
depth, cm (in.)	TBD	TBD
DATA		
voice, hr/day	TBD	TBD
TV, B&W, hr/day		
TV, color, hr/day		
analog, MHz	4(4 hr/day)	2(8 hr/day)
digital, bps	1200	2500

2.4.1 ROLE OF GRAVITY IN MAMMALIAN VITAL FUNCTIONS. The scientific objectives of this experiment class are:

a. To investigate the onset, rate, and extent of changes in vital physiologic functions such as hemodynamic, cardiovascular, respiratory, neuromuscular, musculoskeletal, and tissue-repair responses to the unique environmental factors, particularly weightlessness, experienced in space flight.

Table 2-7. Vertebrate Research Program

Section	Title
2.4.1	Experiment Class: Role of Gravity in Mammalian Vital Functions
2.4.1.1	Experiment: Orbiting subhuman primate
2.4.1.2	Experiment: Cardiovascular adaptation during long-term weightlessness
2.4.1.3	Experiment: Effects of reduced gravity on bioelectric potentials and bone metabolism
2.4.1.4	Experiment: Immune responses of animals
2.4.1.5	Experiment: Tissue and cell morphology with and without endocrine gland ablations
2.4.1.6	Experiment: Tissue growth and repair in weightlessness
2.4.2	Experiment Class: Role of Gravity in Vertebrate Life Processes
2.4.2.1	Experiment: Role of gravity in the life processes of mammals
2.4.2.2	Experiment: Necessity of gravity for normal growth of turtles
2.4.2.3	Experiment: Weightlessness, growth and rhythms
2.4.2.4	Experiment: Effect of weightlessness on chickens
2.4.2.5	Experiment: Circadian rhythms
2.4.2.6	Experiment: Central nervous system function in hibernating or hypothermic mammals in weightlessness
2.4.2.7	Experiment: The role of gravity in avian bone metabolism
2.4.3	Experiment Class: Effect of the Space Environment on Performance and Behavior
2.4.3.1	Experiment: Vestibular research in space
2.4.3.2	Experiment: Vestibular apparatus development
2.4.3.3	Experiment: Neural correlates of function of the mammalian vestibular system
2.4.3.4	Experiment: Effects of changes in gravity on the otolith
2.4.3.5	Experiment: Neural and behavioral development in inbred mice
2.4.3.6	Experiment: Force of isometric contraction of nonvestibular/vestibular muscle in low-gravity environments

b. To apply the results of these investigations to a more complete understanding of any untoward effects on man resulting from long-term space flight.

c. To establish a capability for in-depth studies leading to therapeutic or prophylactic measures should these be required to support longer-term manned-spaceflight missions.

An experiment requirements summary is shown in Table 2-8.

2.4.1.1 Orbiting Sub-Human Primate

2.4.1.1.1 Scientific Objectives

a. Evaluation of cardiovascular function during long-term weightlessness.

b. Evaluation of metabolic functions, especially fluid balance and distribution, during long-term weightlessness.

2.4.1.1.2 Experiment Description. The experimental animals will be adult male monkeys (Macaca nemestrina) weighing 10-12kg (22-26 lb) each. Experimental subjects and control(s) are to be subjected, simultaneously, to the same flight profile. The experimental and mandatory control animals will be identically instrumented, with the same basic data being acquired. If the space laboratory facility has the capability of centrifugation, one or more animals should be placed in this operational mode for additional control information.

Surgical preparation of the animals and instrument implantation will occur a sufficient time before flight to ensure complete recovery. Typical instrumentation to be implanted includes blood-flow sensors, temperature sensors, pressure transducers (arterial and venous), indwelling catheters, ECG electrodes, and transmitter(s).

Restraint of all animals will be necessary with a conformation couch used for animal support. Sufficient restraints will be placed about the body and extremities to prevent the animals from disturbing the experimental setup but allowing freedom of movement for feeding or for performance of specified tasks.

The primates will be transported to the spacecraft in a small module which during launch and reentry will isolate the animals from the crew. The transporter must provide independent short-term life support and waste management systems as well as a means for data collection during launch and recovery. Its design must also be compatible with cargo handling facilities for easy transport.

Baseline control data will be obtained prior to flight for parametric measurements that will be monitored and recorded during flight. Preflight control data will be compared to similar post-flight measurements when live animals are returned to ground for subsequent readaptive studies.

Table 2-8. Experiment Requirements Summary (Class: Role of Gravity in Mammalian Vital Functions)

EXPERIMENT NO. AND TITLE	2411 Orbiting Subhuman Primate		2412 Cardiovascular Adaptation During Long-Term Weightlessness		2413 Effects of Reduced Gravity on Bioelectric Potentials and Bone Metabolism		2414 Immune Response of Animals		2415 Tissue and Cell Morphology With and Without Endocrine Gland Ablations		2416 Tissue Growth and Repair in Weightlessness				NOTES
SPECIMEN	Macaca Nemestrina		Rat		Rat		Ground Squirrel & Golden Syrian Hamster		Rat		Rat				
LOCATION	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	
NO. OF SPECIMENS	4	6	32	64	8	16	10	20	20	40	20	40			
HOLDING CAGES															[1] No periodic cues at whole-number fractions of 24 hours.
Standard	2	2	24	48	4	12	10	20	20	40	20	40			
Metabolic	2		8	16	4	4									
Colony			4	8											
MAN REQUIREMENTS, hr															[2] Normal Laboratory Max.: $\begin{cases} 10^{-3}g\ 90\%\ \text{of time} \\ 10^{-2}g\ 10\%\ \text{of time} \end{cases}$
Skill 1															
Setup	8	12	4	8	2	4	2	4	2	4	1.5	3			
Daily Average [3]	1.5	2	2	4	1	2	0.5	0.1	1	2	3	0.6			
Terminate	8	12	4	8	2	4	2	4			1.5	3			
Skill 3															[3] Ad Hoc observations required up to 8 hr/day. They cannot be scheduled and are part of the daily average. Crew time is average.
Setup															
Daily Average [3]	1	2	1.5	3	2	4	1	2							
Terminate															
Skill 4															[4] SMAC = Space maximum allowable concentration for man.
Setup	1	2	1	2							1	2			
Daily Average [3]	1	2	2	4	1	4			2	4	1.5	3			
Terminate	2	4	1	2					4	8	1	2			
EXPERIMENT DURATION, days	360	360	90	90	21	21	60	60	180	180	15	15			[5] No offensive or noxious odors.
ENVIRONMENTAL REQMTS															[6] TBD; minimal to reasonable engineering design effort.
pO_2, mm Hg	150 ±10	150 ±10	150 ±10	150 ±10	150 ±10	150 ±10	150 ±10	150 ±10	150 ±10	150 ±10	160 ±10	160 ±10			
pN_2 or Total Pressure, mm Hg	TP 760 ±10	TP 760 ±10	TP 760 ±10	TP 760 ±10	TP 760 ±10	TP 760 ±10	TP 760 ±10	TP 760 ±10	TP 760 ±10	TP 760 ±10	TP 760 ±10	TP 760 ±10			[7] Arterial & Venous
pCO_2, mm Hg	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3			
pCO, mm Hg	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01			[8] Includes blood, feces, urine, bacterial, gas, and biopsy samples.
pNH_3, mm Hg	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01			
pH_2O, mm Hg	10-16	10-16	10-16	10-16	10-16	10-16	10-16	10-16	10-16	10-16	14 ±5	14 ±5			
Temperature, °K (°C)	(25 ±1) 298 ±1	(25 ±1) 298 ±1	(25 ±1) 298 ±1	(25 ±1) 298 ±1	(25 ±1) 298 ±1	(25 ±1) 298 ±1	(25 ±1) 298 ±1	(25 ±1) 298 ±1	(25 ±1) 298 ±1	(25 ±1) 298 ±1	*	*			[9] Samples per week/ tests per sample
O_2 Consumption, kg/day	0.46	0.69	0.58	1.16	0.14	0.28	0.18	0.36	0.36	0.72	0.5	0.9			
CO_2, kg/day	0.47	0.71	0.61	1.22	0.15	0.30	0.19	0.38	0.38	0.76	0.5	0.9			
Noise, dB	[6]	[6]	[6]	[6]	[6]	[6]	[6]	[6]	[6]	[6]	[1] min.				
Vibration, g (Hz)	[6]	[6]	[6]	[6]	[6]	[6]	[6]	[6]	[6]	[6]	[1] min.				
Acceleration, g	[2]	[2]	[2]	[2]	[2]	[2]	[2]	[2]	[2]	[2]	[2]	0.5 to			[10] Measurements made at holding unit level only; () = each organism.
Radiation, C/kg	[6]	[6]	[6]	[6]	[6]	[6]	[6]	[6]	[6]	[6]	TBD	1.0			
Illumination, lum/m^2 (ft-c)	(90 ±10) 970 ±100	(90 ±10) 970 ±100	(90 ±10) 970 ±100	(90 ±10) 970 ±100	(90 ±10) 970 ±100	(90 ±10) 970 ±100	(90 ±10) 970 ±100	(90 ±10) 970 ±100	(90 ±10) 970 ±100	(90 ±10) 970 ±100	**	**			
Trace Contaminants	[5] [4]	[5] [4]	[5] [4]	[4] [5]	[4] [5]	[4] [5]	[4] [5]	[4] [5]	[4] [5]	[4] [5]	[4] [5]	[4] [5]			
NUMBER AND FREQUENCY OF MEASUREMENTS															*297 to 300 (24 to 27) **1100 ± 100 (100 ± 10)
Animal Activity, continuous	2	4	8	16	8	16									
ECG, 2 times/day	2	4	8	16	8	16									
EEG, 2 times/day	2	4	4	8	2	4									
EMG, 2 times/day					4	8									
Respiratory Rate, 2 times/day	2	4	8	16	4	8									
CO_2 Production, cont.	2		8	16	4	4									
O_2 Consumption, cont.	2		8	16	4	4									
Thermal Output, cont.	2		8	16	4	4									
Cardiac Output, daily	2														
Body Temp, 4/day	2	4	8	16	4	4									
Food Consump., daily	4	6	8	16	4	4	10	20	20	40					
Water Consump., daily	4	6	8	16	4	4	10	20	20	40					
Musculoskeletal Tonus, daily															
Urine Output, 4/day	2		8	16	4	4									
Feces Output, daily	2		8	16	4	4									
Hematologies [9]	2/6	4/6	8/8	16/8											
Chemistries [9]	2/10	2/10	8/10	16/10	4/4	8/4					14/4	28/4			
Serologies [9]							5/10	5/10							
Radiochemistries/wk											14				
Histologies [9]									1/8	2/8	14/4	28/4			
Bacterial Counts/wk															
Bacterial Assay/wk											7	14			
Blood Pressure, daily	2	4	8	16											
Blood Gases pO_2, pCO_2, pH, weekly			8	16											
Event Start & Stop	X	X													
Total Body Water, weekly	2	4													
Total Body Weight, weekly	2	4									20	40			
Extracellular Fluid	2	4													

Table 2-8. Experiment Requirements Summary (Class: Role of Gravity in Mammalian Vital Functions), Contd

EXPERIMENT NO.	2411		2412		2413		2414		2415		2416				
LOCATION	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	NOTES
NUMBER AND FREQUENCY OF MEASUREMENTS															
Samples [8] Prep for Earth Return/wk	2	4			4	4									
pO_2, hourly	4	6	2	4	1	2	1	2	1	2	1	2			
pCO_2, hourly [10]	4	6	2	4	1	2	1	2	1	2	1	2			
pNH_3, hourly [10]	4	6	2	4	1	2			1	2	1	2			
pH_2O, hourly [10]	4	6	2	4	1	2	1	2	1	2	1	2			
Temp., hourly [10]	4	6	2	4	1	2	1	2	1	2	1	2			
Noise, continuous [10]	4	6	2	4	1	2	1	2			1	2			
Vibration, cont. [10]	4	6	2	4	1	2	1	2	1	2	1	2			
Acceleration, cont. [10]	4	6	2	4	1	2	1	2	1	2	1	2			
Radiation, cont. [10]	4	6	2	4	1	2	1	2	1	2	1	2			
Organism Sacrifice/wk									0.5	1	***				
Urine Analysis/wk	4	6	8	16	4	8			5	10					
Organism Visual Monitorings/wk	14	28			7	9			7	7	7	7			
Organism Recovery Preparation, No.	4	6							5	10	10	20			
Organism Live Recovery, No.	4	6			4	8			5	10	10	20			
Illumination, No./meas.	4	6	32	64	8	16			20	40	1	2			
Radiobiologies/wk					4	8					10	20			
POWER															OTHER
AC															
Continuous, watts	80	120	120	240	100	200	30	60	60	120	60	120			***After 5 days 2/mo
Peak, watts	100	140	160	320	100	200	30	60	60	120					
Peak Duration, min/day	60	60													
DC															
Continuous, watts	20	30	40	80	30	60	5	10	10	20	5	10			
Peak, watts															
Peak Duration, min/day															
WEIGHT															
Organisms and Cages, kg (lb)	48 (106)	72 (158)	10 (22)	20 (44)	16 (35)	32 (70)	2 (4.4)	4 (9)	15 (33)	30 (66)	25 (55)	30 (66)			
Ancillary Research Equipment, kg (lb)	50 (110)	60 (132)	10 (22)	20 (44)	8 (18)	10 (22)	2 (4.4)	4 (9)	4 (9)	4 (9)	10 (22)	12 (24)			
VOLUME															
Organisms and Cages, m^3 (ft^3)	8 (283)	12 (425)	0.25 (8.8)	0.5 (18)	0.25 (8.8)	0.5 (18)	0.1 (3.5)	0.2 (7)	0.2 (7)	0.3 (11)	0.2 (7)	0.3 (11)			
Ancillary Research Equipment, m^3 (ft^3)	0.1 (3.5)	0.15 (5.3)	0.01 (0.35)	0.02 (0.7)	0.01 (0.35)	0.02 (0.7)	0.01 (0.35)	0.02 (0.7)	0.01 (0.35)	0.02 (0.7)	0.02 (0.7)	0.02 (0.7)			
LOGISTICS															
Weight at Launch, kg (lb)	440 (970)	610 (1347)	70 (154)	140 (309)	75 (166)	140 (309)	20 (44)	40 (88)	50 (110)	90 (198)	50 (110)	92 (203)			
Supplies/Mo. Up, kg (lb)	240 (530)	360 (795)	50 (110)	100 (220)	45 (99)	90 (198)	15 (33)	30 (66)	25 (55)	50 (110)	25 (55)	50 (110)			
Supplies/Mo. Down, kg (lb)	190 (419)	290 (640)	40 (88)	80 (172)	36 (79)	72 (159)	12 (26)	24 (53)	20 (44)	40 (88)	25 (55)	50 (110)			
Weight at Termination, kg (lb)	175 (386)	265 (585)	38 (84)	75 (166)	34 (75)	68 (150)	11 (24)	22 (49)	20 (44)	40 (88)	50 (110)	90 199			
Volume at Launch, m^3 (ft^3)	0.9 (31)	1.4 (50)	0.3 (11)	0.6 (21)	0.3 (11)	0.6 (21)	0.12 (4.2)	0.24 (8.5)	0.12 (4.2)	0.24 (8.5)	0.12 (4.3)	0.24 (8.5)			
Supplies/Mo. Up, m^3 (ft^3)	0.5 (18)	0.7 (25)	0.3 (11)	0.6 (21)	0.3 (11)	0.6 (21)	0.2 (7)	0.4 (14)	0.15 (5.3)	0.3 (11)	0.15 (5.3)	0.3 (11)			
Supplies/Mo. Down, m^3 (ft^3)	0.4 (14)	1.5 (53)	0.2 (7)	0.4 (14)	0.2 (7)	0.4 (14)	0.1 (3.5)	0.2 (7)	0.1 (3.5)	0.2 (7)	0.1 (3.5)	0.2 (7)			
Volume at Termination	0.8 (28)	1.2 (42)	0.25 (9)	0.5 (18)	0.25 (9)	0.5 (18)	0.1 (3.5)	0.2 (7)	0.1 (3.5)	0.2 (7)					
Frozen Specimens Down	X	X	X	X	X	X	X	X	X	X	X	X			
Live Organisms Up	X	X	X	X	X	X	X	X	X	X	X	X			
Live Organisms Down	X	X	X	X	X	X	X	X	X	X	X	X			
Frozen Specimens Up															
Other															
COMMUNICATIONS															
Voice, hr/day	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD			
TV, B&W, hr/day	0.5	1	0.5	1	0.5	1	0.5	1	0.5	1	X	X			
TV, Color, Ad Hoc	X	X	X	X	X	X	X	X	X	X	X	X			

Physiological and environmental data will be monitored and recorded during selected segments of the liftoff sequence and into orbital flight. Similarly, when animals are returned alive, data for the initiation, deorbiting, reentry and recovery phases of flight will be recorded. Periodic recording will occur throughout each 24-hour interval during orbital flight.

2.4.1.1.3 Observation/Measurement Program. During flight, the animals will be restrained in a couch to the extent necessary to prevent interference with instrumentation leads to and from the implanted sensors and his immediate surroundings. Where feasible, vital-function data will be recorded during liftoff and entry into orbital flight, and during the stages of reentry, as well as during orbital flight.

Direct and TV monitoring will be utilized to determine behavior and general well-being of the primate. Observations include eye movements and lustre, manual dexterity, feeding and drinking, etc. These observations will also check and confirm proper functioning of all experimental subsystems.

The following measurements will be made:

a. Cardiovascular: heart rate, EKG, arterial and venous pressure, arterial and venous blood flow, and pulse pressure.

b. Hemodynamic: blood volume, % hemoglobin, plasma protein, cardiac output (direct), and arterial and venous pO_2.

c. Metabolic: Ca^{++}, H_2O & N_2 balance, caloric balance, body temperature, and body mass.

d. Respiratory: rate, volume, and O_2/CO_2 exchange.

e. Biochemical analyses: blood, urine, and feces analyses compatible with CORE capability.

Fecal and urinary outputs will be separately collected in four-hour aliquots on a continuous schedule. Initial determinations will be made of feces mass, dry weight, and color, and of urine volume, specific gravity, color, and pH.

Analysis of urine and feces will be conducted to determine metabolic balance, endocrine activity, etc., as defined in the CORE. If the necessary analyses cannot be performed on board, appropriate sub-aliquots of the four-hour samples must be preserved (chemical or low-temperature) and returned for ground-based study.

The frequency and extent of any or all of the observations and measurements will be subject to modifications as dictated by physiologic or behavioral changes in the subject during the course of the experiment.

Studies of the microflora of the animal will be made during the spaceflight. Samples must be taken and prepared for analysis. Identification of the organisms and population studies must be made.

In some instances behavioral studies will be carried out employing operant conditioning regimes using food and water as rewards. Activity will be monitored within the primate facility between restraint intervals. Television monitoring will be used and provision must be made for low-light-intensity TV monitoring.

Returned animals will be used in readaptive studies, breeding studies for genetic effects, and histological and histochemical analyses.

Radiation monitoring must occur at all times for accumulated dose and spectral and peak energies.

2.4.1.1.4 Interface, Support and Performance Requirements. General environment requirements are:

a. Temperature: 297-301°K (24-28°C)

b. Relative humidity: 40-70%

c. Total pressure: 1 atmosphere

d. Gas partial pressures: O_2, 21 kN/m^2 (3.0 psia); N_2, 81 kN/m^2 (11.7 psia); CO_2, 41.5 N/m^2 (0.006 psia)

e. Contaminant control: No offensive odors and noxious/toxic gases

f. Isolation: Noise and visual isolation from non-experiment related sources

The animal enclosure envelope is 1 x 1 x 1.5 m (3.3 x 3.3 x 4.92 ft) and weighs 225 kg (495 lb) for the enclosure and instrumentation. Power required is 28 V dc, 300 watts (avg). Data requirements are 10 to 15 continuous physiological parameters at 10 samples/sec, with 8 bits/sample, for a total of 1200 bps. Lighting requirements are 12 hours light, 12 hours dark, with light level during dark period to allow vidicon observation. Signal conditioning must be provided for physiological sensors and for environmental control and life support measurements. Periodic data collection, storage and readout, and display and control panels for monitoring and switching operations must be provided.

2.4.1.1.5 Potential Role of Man. Man will monitor animal and physiological data, collect blood, urine and fecal samples, analyze specimens and samples, perform experimental procedures, maintain food and water supply, and transfer to and from Shuttle vehicle.

2.4.1.2 Cardiovascular Adaptation During Long-Term Weightlessness. The objective of this experiment is to determine the nature, time course, and final extent of cardiovascular changes in mammals exposed to conditions of space flight over long periods of time.

2.4.1.3 Effects of Reduced Gravity on Bioelectric Potentials and Bone Metabolism. The objective of this experiment is to derive a theory to explain the mechanism of the apparent loss of bone calcium during weightlessness.

2.4.1.4 Immune Response of Animals. The objective of this experiment is to demonstrate that the weightlessness state alone or coupled with isolation may exert a depressing effect on the synthesis of circulating antibody.

2.4.1.5 Tissue and Cell Morphology With and Without Endocrine Gland Ablation. The objective of this experiment is to determine whether the deleterious effects of prolonged weightlessness will be cumulative and, therefore, will become imprinted ultimately on the morphology of susceptible organs and tissues.

2.4.1.6 Tissue Growth and Repair in Weightlessness. Growth (mitosis) is gravity-dependent: (1) Does weightlessness interfere with tissue repair? (2) What role does gravity play in influencing growth and development?

2.4.2 THE ROLE OF GRAVITY IN VERTEBRATE LIFE PROCESSES. The scientific objectives of this experiment class are:

a. To study the role of gravity and other environmental factors such as radiation in vertebrate reproductive processes, embryogenesis, parturition growth, development, maturation, nutrition agency, and longevity using a wide variety of representatives from the phylogenetic series.

b. To apply the results of these studies to the better understanding of biological processes and to the resolution of extant problems in health, ecology, and environment that are amenable to biological solution.

An experiment requirements summary is shown in Table 2-9.

2.4.2.1 Role of Gravity in the Life Processes of Mammals

2.4.2.1.1 Scientific Objectives. To determine the effects of the space environment on reproduction, intrauterine development, postpartum growth and development, maturation, and aging processes. Specific questions to be answered are:

a. Will a normal estrual cycle occur in weightlessness?

b. Will copulation be successful and result in fertilized ova?

c. Will normal implantation and development occur following fertilization?

Table 2-9. Experiment Requirements Summary (Class: Role of Gravity in Vertebrate Life Processes)

EXPERIMENT NO. AND TITLE	2421 Role of Gravity in the Life Processes of Mammals		2422 Necessity of Gravity for Normal Growth of Turtles		2423 Weightlessness, Growth and Rythms		2424 Effect of Weightlessness on Chickens		2425 Circadian Rhythms		2426 Central Nervous System Function in Hibernating or Hypothermic Mammals in Weightlessness		2427 The Role of Gravity in Avian Bone Metabolism		NOTES
SPECIMEN	Rat Mouse Hamster		Box Turtle Hatchlings		Rat		Chicken		C-Mice Pocket Mice		Marmot Hamster		Japanese Quail		
LOCATION	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	
NO. OF SPECIMENS	48	96	6	12	88	176	6	12	20	40	6	12	30	60	[1] No periodic cues at whole-number fractions of 24 hours.
HOLDING CAGES															[2] Normal Laboratory Max.: $\begin{cases} 10^{-3}\text{g } 90\% \text{ of time} \\ 10^{-2}\text{g } 10\% \text{ of time} \end{cases}$
Standard	32	64	6	12	88	176	6	12	20	40			20	40	
Metabolic	16	32									6	12	10	20	
Colony															
MAN REQUIREMENTS, hr															[3] Ad Hoc observations required up to 8 hr/day. They cannot be scheduled and are part of the daily average. Crew time is average.
Skill 1															
Setup	4	8	1	2	4	8	2	4	1	2	2	4	2	4	
Daily Average [3]	1	2	0.2	0.4	2	4	1	2	0.5	1	0.5	1	0.5	1	
Terminate	4	8	2	4	4	8	2	4			2	4	2	4	
Skill 3															
Setup															
Daily Average [3]	1	2													
Terminate							0.5	1							
Skill 4															
Setup	1	2			4	8									
Daily Average [3]					4	8	1	2			1.5	3	1.5	2	
Terminate	1	2			8	16	2	4							
EXPERIMENT DURATION, days	300	300	70	70	150	150	180	180	42-90	42-90	175	175	20	20	[4] SMAC = Space maximum allowable concentration for man.
ENVIRONMENTAL REQMTS															[5] No offensive or noxious odors.
pO_2, mm Hg	150±10	150±10	150±10	150±10	150±10	150±10	150±10	150±10	150±10	150±10	150±10	150±10	150±10	150±10	[6] TBD; minimal to reasonable engineering design effort.
pN_2 or Total Pressure, mm Hg	760±10	760±10	760±10	760±10	760±10	760±10	760±10	760±10	760±10	760±10	760±10	760±10	760±10	760±10	
pCO_2, mm Hg	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	[7] Arterial & Venous
pCO, mm Hg	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	[8] Includes blood, feces, urine, bacterial, gas, and biopsy samples.
pNH_3, mm Hg	<0.01	<0.01									<0.01	<0.01	<0.01	<0.01	
pH_2O, mm Hg	16-20	16-20			16-20	16-20	7-10	7-10					10-16	10-16	
Temperature, °K (°C)	298±1 (25±1)	298±1 (25±1)	299-303 (26-30)	299-303 (26-30)	298±1 (25±1)	298±1 (25±1)	294±2 (21±2)	294±2 (21±2)					295±1 (22±1)	295±1 (22±1)	[9] Samples per week tests per sample
O_2 Consumption, kg/day	0.84	1.68			1.54	3.08					0.16 (0.36)				
CO_2, kg/day	0.88	1.96			1.6	3.2					0.17				[10] Measurements made at holding unit level only; () = each organism.
Noise, dB	[6]	[6]	TBD [6]	TBD [6]	TBD [6]	TBD [6]	Nominal [6]	Nominal [6]			[6]		[6]	[6]	
Vibration, g (Hz)	[6]	[6]									[6]		[6]		
Acceleration, g	[2]	0.5 to 1	[2]	1	[2]	1					[2]	1	[2]	0.5 to 1	
Radiation, C/kg	[6]	[6]	[6]	[6]	[6]	[6]					[6]		[6]	[6]	
Illumination, lum/m^2 (ft-c)	970±100 (90±10)	970±100 (90±10)	970±100 (90±10)	970±100 (90±10)	970±100 (90±10)	970±100 (90±10)	970±100 (90±10)	970±100 (90±10)							
Trace Contaminants															
NUMBER AND FREQUENCY OF MEASUREMENTS: Animal Activity, continuous	8	16			16	32			20	40	6	12			
ECG, 2 times/day			6	12	8	16					3	6			
EEG, 2 times/day											3	6			
EMG, 2 times/day			6 4x/day	12 4x/day							3	6			
Respiratory Rate, 2 times/day	16	32													
CO_2 Production, cont.	16	32									3	6			
O_2 Consumption, cont.	16	32													
Thermal Output, cont.	16	32									3	6			
Cardiac Output, daily											1	2			
Body Temp, 4/day	16	32									3	6			
Food Consump., daily	16	32	6	12							6	12			
Water Consump., daily	16	32									6	12			
Musculoskeletal Tonus, daily					16	32									
Urine Output, 4/day	16	32									6	12			
Feces Output, daily	16	32									6	12			
Hematologies, 1/week	8	16					2	4			6	12			
Chemistries [9]	8/6	8/6			3/6	6/6					3/6	6/6	10/6	20/6	
Serologies [9]															
Radiochemistries/wk															
Histologies [9]	4/8	.8/8					2	4			3/TBD	6/TBD			
Bacterial Counts/wk															
Bacterial Assay/wk															
Blood Pressure, daily											3	6			
Blood Gases pO_2, pCO_2, pH, 1/week											3	6			
Event Start & Stop	48	96									6	12			
Total Body Water, each week					8	16									
Total Body Weight, each week					16	32							30	60	
Extracellular Fluid															

Table 2-9. Experiment Requirements Summary (Class: Role of Gravity in Vertebrate Life Processes), Contd

EXPERIMENT NO.	2421		2422		2423		2424		2525		2426		2427		NOTES
LOCATION	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	
NUMBER AND FREQUENCY OF MEASUREMENTS															
Samples [8] Prep for Earth Return/wk	16	32			3	6									
pO_2, hourly	3(16)	6(32)			4	8	2	3	1	2	6 Cont	12 Cont	1	2	
pCO_2, hourly [10]	3(16)	6(32)			4	8			1	2	6 Cont	6 Cont	1	2	
pNH_3, hourly [10]	3	6									6	12			
pH_2O, hourly [10]	3	6	2	4	4	8			1	2	6	12			
Temp., hourly [10]	3(16)	6(32)	2	4			2	3	1	2	6	12	1	2	
Noise, continuous [10]	3	6							1	2	2	3	1	2	
Vibration, cont. [10]	3	6							1	2	2	3			
Acceleration, cont. [10]	3	6							1	2	2	3	1	2	
Radiation, cont. [10]											2	3	1	2	
Organism Sacrifice/wk	2	4													
Urine Analysis/wk	8	16													
Crew observation/week (total experiment)	14	14	7	7							7	7			
Surgeries/week	8	16													
Radio Chemistries per week	8	16					3	6					10	20	
Manage space born organisms	X	X													
X-ray no./week	8	16											10	20	
Organism linear measurements no./ week			6	12											
Illumination, No/meas.			2	4									30	60	
Total pressure, hourly [10]			2	4			2	3							
Oviposition													30	36	
POWER															OTHER
AC															
Continuous, watts	100	200	35	70	150	300	20	40	20	40	25	50	35	70	
Peak, watts															
Peak Duration, min/day															
DC															
Continuous, watts	20	40	42	42	20	40	10	20	20	40	5	5	5	10	
Peak, watts															
Peak Duration,															
WEIGHT															
Organisms and Cages, kg (lb)	20(44)	40(88)	15(33)	30(66)	35(77)	70(154)	10(22)	20(44)	5(11)	10(22)	35(77)	70(154)	10(22)	20(44)	
Ancillary Research Equipment, kg (lb)	20(44)	25(55)	5(11)	10(22)	20(44)	40(88)	10(22)	20(44)	1(2.2)	2(4.4)	4.5(10)	9(20)	2(4.4)	4(9)	
VOLUME															
Organisms and Cages, m^3 (ft^3)	0.5(18)	1(35)	0.16 (5.7)	0.32 (11.3)	0.5(18)	1(35)	0.2(7)	0.4(14)	0.05 (1.8)	0.1 (3.5)	0.6(21)	1.2(42)	0.12 (4.2)	0.24 (8.4)	
Ancillary Research Equipment, m^3 (ft^3)	0.1 (3.5)	0.1 (3.5)	0.1 (3.5)	0.1 (3.5)	0.1 (3.5)	0.1 (3.5)	0.1 (3.5)	0.2 (7)	0.02 (0.7)	0.04 (1.4)	0.1 (3.5)	0.1 (3.5)	0.08 (2.8)	0.10 (3.5)	
LOGISTICS															
Weight at Launch, kg (lb)	65 (143)	115 (253)	22 (49)	34 (75)	100 (220)	200 (441)	25 (55)	50 (110)	7 (15)	14 (31)	60 (132)	120 (264)	42 (92)	84 (185)	
Supplies/Mo. Up, kg (lb)	25 (55)	50 (110)	2 (4.4)	4 (9)	45 (99)	90 (198)	5 (11)	10 (22)	1 (2.2)	2 (4.4)	20 (44)	40 (88)	30 (66)	60 (132)	
Supplies/Mo. Down, kg (lb)	20 (44)	40 (88)	1.6 (3.5)	3.2 (7)	36 (79)	72 (159)	4 (9)	8 (18)	0.8 (1.8)	1.6 (3.5)	16 (35)	30 (66)	25 (55)	50 (110)	
Weight at Termination, kg (lb)	60 (132)	100 (220)	20 (44)	30 (33)	100 (220)	200 (441)	22 (49)	45 (99)	6 (13)	12 (26)	60 (132)	120 (264)	40 (88)	80 (172)	
Volume at Launch, m^3 (ft^3)	0.8(14)	1.5(53)	0.32 (11)	0.43 (15)	1.4(50)	2.8 (100)	0.3 (11)	0.5 (18)	0.07 (2.5)	0.14 (5)	0.7 (24)	1 (35)	0.2 (7)	0.34 (12)	
Supplies/Mo. Up, m^3 (ft^3)	0.2 (7)	0.4 (14)	0.02 (0.7)	0.04 (1.4)	0.4 (14)	0.8 (28)	0.1 (3.5)	0.2 (7)	0.02 (0.7)	0.04 (1.4)	0.05 (1.8)	0.05 (1.8)	0.1 (3.5)	0.2 (7)	
Supplies/Mo. Down, m^3 (ft^3)	0.2 (7)	0.3 (11)	0.02 (0.7)	0.03 (1.1)	0.3 (11)	0.6 (21)	0.08 (2.8)	0.16 (5.7)	0.02 (0.7)	0.03 (1.1)	0.04 (1.4)	0.04 (1.4)	0.08 (2.8)	0.16 (5.6)	
Volume at Termination															
Frozen Specimens Down	X	X			X	X	X	X					X	X	
Live Organisms Up	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
Live Organisms Down	X	X	X	X	X	X					X	X	X	X	
Frozen Specimens Up															
Other															
COMMUNICATIONS															
Voice, hr/day	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	
TV, B&W	X	X	X	X	X	X	X	X	X	X	YES	YES	YES	YES	
TV, Color, Ad Hoc	X	X	X	X	X	X	X	X	X	X	X	X	X	X	

d. Will normal embryonal and fetal development occur and lead to normal parturition?

e. Can adequate post-natal care be given, e.g., cleaning, nursing, etc.?

f. Will normal infants grow and develop at a normal rate in weightlessness?

g. What is the effect of weightlessness on maturation, aging and longevity?

This experiment is a long-term complex team effort which can be successful only in a true laboratory situation. With more limited spacecraft capabilities, the objectives can be achieved by a series of shorter experiments conducted in appropriate sequences.

2.4.2.1.2 Experiment Description. Male and female rats (or mice) will be caged separately and taken into orbit. The approach of female fertility will be monitored by microscopic examination of vaginal epithelial smears. At the beginning of the estrual cycle proven males will be introduced into the cage. Behavior of the animals during the cycle will be observed and recorded by TV or cinematography.

Selected pregnant females will be surgically examined and embryos and fetuses collected for histological study. Implantation sites will be noted and uterine contents photographed. Females so operated may be allowed to recover and observed for wound healing. They may also serve as subjects in other studies not related to reproduction. Where pregnancy does not occur, both males and females will be examined to determine the possible cause(s).

Parturition and post-natal behavior will be observed and recorded. Growth curves will be established for comparison with ground controls. Parallel studies will be conducted on the bioresearch centrifuge if it is available.

Animals will be sacrificed periodically during the life of the experiment to determine organ size and weight. Histological and biochemical examinations of the organs and tissues will also be done.

Additional supporting studies include periodic (e.g., weekly) examination of blood and urine for variations in specific metabolic and endocrine function. Overall metabolism will be monitored by use of radioisotope marked foods and respiratory gas exchange. Metabolic and regulator functions will be further studied by endocrine gland ablation and experimentally induced renal calculi.

2.4.2.1.3 Observation/Measurement Program. Direct observations and TV/cinematography coverage will be continuous during estrual activity and during parturition and immediate post-parturition periods, and intermittent for locomotion, feeding and general behavior. Histology/cytology observations include vaginal epithelium smears daily, prior to estrus; placentation; periodic histologic and cytologic examination of embryos and fetuses during gestation (frequency TBD), and periodic examination of organs and tissues through the life cycle (frequency TBD).

Metabolic studies include:

a. Analysis of blood and urine for selected components (weekly).

b. Metabolic pathway studies using C^{14} isotope tagged substrates. Monitor $C^{14}O_2$ production and autoradiographs.

c. Respiratory gas exchange (O_2 consumption, CO_2 production). Frequency of measurement TBD.

Environmental data includes:

a. Temperature, pressure and gas composition measured with a frequency to ensure values remain within limits.

b. Acceleration/vibration recorded (frequency, amplitude, direction).

2.4.2.1.4 Interface, Support and Performance Requirements. General environmental requirements are:

a.	Temperature	299 ± 2°K (26°C ± 2°C)
b.	Relative Humidity	60% ± 10%
c.	Pressure	1 Earth Atmosphere
d.	pO_2	150 mm Hg ±5 mm Hg
e.	pN_2	700 mm Hg ±5 mm Hg
f.	pCO_2	2 mm Hg ±2 mm Hg
g.	Other gases	TBD (Below Toxic Levels)
h.	Lighting	12 hours light/12 hours dark (suitable for photography and TV)

Experiments will interface with the CORE and other support units required for FPE 2. Breeding and nesting cages must be designed to provide firm toeholds.

2.4.2.1.5 Potential Role of Man. The role of man will include housekeeping (i.e., laboratory maintenance and animal care) and the following experiment-related activities:

a. Experiment setup

b. Animal handling and monitoring

c. Anatomical specimen preparation for gross and microscopic examination

d. Biochemical and chemical analyses

e. Experiment termination preparation of material, specimens, and animals for return to Earth experimentation

f. Photography.

2.4.2.1.6 Available Background Data

a. Bioscience Research During Earth-Orbiting Missions: Manned Orbital Space Station; Contract NASr-132 AIBS; Final Report, January 1968.

b. Space Biology Report of a Study Convened by the Space Science Board, NAS-NRC, 1970.

2.4.2.2 Necessity of Gravity for Normal Growth of Turtles. The objective of this experiment is to determine effects of weightlessness upon the growth of hatchling turtles.

2.4.2.3 Weightlessness, Growth and Rhythms. The objective of this experiment is to monitor the major body organs for composition and mass and relate these to circadian-rhythm alterations.

2.4.2.4 Effect of Weightlessness on Chickens. The objective of this experiment is to study the effects of weightlessness on the physiological processes of chickens.

2.4.2.5 Circadian Rhythms. This experiment is expected to resolve the following questions: (1) Is the biological clock endogenous or exogenous? (2) Are changes in one observed rhythm correlatable to changes in other rhythms in space?

2.4.2.6 Central Nervous System Function in Hibernating or Hypothermic Mammals in Weightlessness. This experiment has two primary objectives:

a. To determine whether the animal remains in or returns to hibernation upon exposure to weightlessness.

b. To determine whether the modes of information handling by the central nervous system during hibernation and hypothermic are altered by the space environment.

2.4.2.7 The Role of Gravity in Avian Bone Metabolism. The objective of this experiment is to determine the influence of dietary calcium adaptation in coturnix japonica on endocrine metabolism and skeletal turnover under weightless conditions.

2.4.3 EFFECT OF THE SPACE ENVIRONMENT ON PERFORMANCE AND BEHAVIOR. The experiment class scientific objectives are to determine:

a. The effects of weightlessness and other space flight stresses, such as radiation and altered geophysical periodicity, upon behavior and performance.

b. The behavior and performance characteristics of animals representing different phylogenetic levels and at different functional levels. Included in the functional levels are:

 1. Response to orientation cues such as visual, vestibular and tactile perception.

 2. Locomotion and other complex neuromuscular functions.

 3. Learning, memory, and the persistence of conditioned responses.

An experiment requirements summary is shown in Table 2-10.

2.4.3.1 Vestibular Research In Space.

2.4.3.1.1 Experiment Objective. To determine the effects of prolonged weightlessness upon the vestibular system through observation of the behavioral response of normal and blinded fish to linear accelerations imposed during weightlessness.

2.4.3.1.2 Experiment Description. A number of small fish are to be used in this experiment, several of them blinded surgically. The animals are contained in a transparent tank filled with fresh water. The tank is mounted so that controlled oscillatory linear accelerations may be impressed on the container. Orientation and other responses will be recorded by television monitors and/or cinematography. Food must be added periodically, and feeding behavior recorded. Results of this study will be compared with the response of small vertebrates that have been reared in space and those taken to space.

2.4.3.1.3 Observation/Measurement Program. The behavior and activity levels of the fish will be observed and recorded by television and/or cinematography in three planes. Records will be taken in the quiet mode as well as during acceleration and during feeding. Acceleration rates, directions, and durations must be recorded in a manner suitable to coordinate in time with behavioral records.

Environmental measurements and control requirements are:

a.	Temperature	293° ±5° K (20 ±5° C)
b.	Dissolved gas tension	Equilibrium with pure air at 1 atmosphere pressure
c.	Pressure	1 atmosphere
d.	pH	TBD

Table 2-10. Experiment Requirements Summary (Class: Effect of Space Environment on Performance and Behavior)

EXPERIMENT NO. AND TITLE	2431 Vestibular Research in Space		2432 Vestibular Apparatus Development		2433 Neural Correlates of Function of the Mammalian Vestibular System		2434 Effects of Changes in Gravity on the Otolith		2435 Neural & Behavioral Development in inbred Mice		2436 Force of Isometric Contraction of Non-Vestibular/ Vestibular Muscle in Low-Gravity Environments				NOTES
SPECIMEN	Goldfish		Rats		Mice		Rats		Mice		Rats				
LOCATION	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	
NO. OF SPECIMENS	6	12	32	64	6	NA	16	32	10	20	20	40			
HOLDING CAGES															[1] No periodic cues at whole-number fractions of 24 hours.
Standard	Special	Special	32	64							20	40			
Metabolic	Special	Special													
Colony	Special	Special			1										
MAN REQUIREMENTS, hr															[2] Normal Laboratory Max.: 10^{-3}g 90% of time, 10^{-2}g 10% of time
Skill 1															
Setup	2	4	2	4			2	4	1	2	2	4			
Daily Average [3]	0.1	0.1	0.1	0.1			0.2	0.4	0.5	0.5	0.5	1			
Terminate	2	4	2	4			2	4			2	4			
Skill 3															[3] Ad Hoc observations required up to 8 hr/day. They cannot be scheduled and are part of the daily average. Crew time is average.
Setup							2	4							
Daily Average [3]							2	4							
Terminate							2	4							
Skill 4															
Setup															
Daily Average [3]			2	4			1	2							
Terminate															
EXPERIMENT DURATION, days	60	60	30	30	90		30	30	10	10	40	40			[4] SMAC = Space maximum allowable concentration for man.
ENVIRONMENTAL REQMTS															[5] No offensive or noxious odor.
pO_2, mm Hg	150±10	150±10	150±10	150±10	150±10		150±10	150±10	150±10	150±10	150±10	150±10			[6] TBD; minimal to reasonable engineering design effort.
pN_2 or Total Pressure, mm Hg	760±10	760±10	760±10	760±10	760±10		760±10	760±10	760±10	760±10	760±10	760±10			
pCO_2, mm Hg			<3	<3	<3		<3	<3	<3	<3	<3	<3			[7] Arterial & Venous
pCO, mm Hg			<0.01	<0.01	<0.01		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01			[8] Includes blood, feces, urine, bacterial, gas, and biopsy samples.
pNH_3, mm Hg			<0.01	<0.01	<0.01		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01			
pH_2O, mm Hg			16-20	16-20	16-20		16-20	16-20	16-20	16-20	16-20	16-20			
Temperature, °K (°C)	294±4 (21±4)	294±4 (21±4)	298±1 (25±1)	298±1 (25±1)	298±1 (25±1)		298±1 (25±1)	298±1 (25±1)	298±1 (25±1)	298±1 (25±1)	298±1 (25±1)	298±1 (25±1)			[9] Samples per week/ tests per sample
O_2 Consumption, kg day			0.56	1.12			0.28	0.56			0.36	0.72			
CO_2, kg day			0.58	1.16			0.29	0.58			0.38	0.76			
Noise, dB	TBD	TBD			[6]		TBD	TBD			[1] [6]	[1] [6]			[10] Measurements made at holding unit level only; () = each organism.
Vibration, g (Hz)	[1]				[1]						[6]	[6]			
Acceleration, g	[2]	0.5g 1g	[2]	0.5g 1g	[2]		[2]	1g			[2]	1g			
Radiation, C/kg					[6]						[6]	[6]			
Illumination, lum/m^2 (ft-c)											970±100 (90±10)	970±100 (90±10)			
Trace Contaminants			[4]	[4]	[4]						[4] [5]	[4] [5]			[11] Requires zero-torque, vent holding unit, and special linear accelerator.
NUMBER AND FREQUENCY OF MEASUREMENTS															
Animal Activity, continuous	6	12	32	64	6		16	32			20	40			
ECG, 2 times/day															
EEG, 2 times/day															
EMG, 2 times/day															
Respiratory Rate, 2 times/day															
CO_2 Production, cont.															
O_2 Consumption, cont.															
Thermal Output, cont.															
Cardiac Output, daily															
Body Temp, 4/day															
Food Consump., daily											20	40			
Water Consump., daily											20	40			
Musculoskeletal Tonus, daily															
Urine Output, 4/day															
Feces Output, daily															
Hematologies 1/week															
Chemistries [9]															
Serologies [3]															
Histologies [9]					1/2										
Bacterial Counts/wk															
Bacterial Assay/wk															
Blood Pressure, daily															
Blood Gases pO_2, pCO_2, pH, weekly															
Event Start & Stop															
Total Body Water, weekly															
Total Body Weight, weekly															
Extracellular Fluid															

Table 2-10. Experiment Requirements Summary (Class: Effect of Space Environment on Performance and Behavior), Contd

EXPERIMENT NO.		2431 [11]		2432		2433		2434		2435		2436				NOTES
LOCATION		Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	
NUMBER AND FREQUENCY OF MEASUREMENTS	Samples [8] Prep for Earth Return/wk															
	pO_2, hourly			1	2	1		1	2	1	1	1	2			
	pCO_2, hourly [10]			1	2	1		1	2	1	1	1	2			
	pNH_3, hourly [10]			1	2	1		1	2	1	1	1	2			
	pH_2O, hourly [10]			1	2	1		1	2	1	1	1	2			
	Temp., hourly [10]			1	2	1		1	2	1	1	1	2			
	Noise, continuous [10]			1	2	1		1	2	1	1	1	2			
	Vibration, cont. [10]			1	2	1		1	2	1	1	1	2			
	Acceleration, cont. [10]			1	2	1		1	2	1	1	1	2			
	Radiation, cont. [10]			1	2	1		1	2	1	1	1	2			
	Organism Sacrifice/wk					0.5										
	Urine Analysis/wk															
	Substrate pH/week	7	7													
	Crew Observation/wk	7	7	7	7	7	7	7	7	7	7	7	7			
POWER																OTHER
AC																
	Continuous, watts			10	20	30		5	10			30	60			
	Peak, watts															
	Peak Duration, min/day															
DC																
	Continuous, watts	7	14	5	10	5		5	10			10	20			
	Peak, watts	60	120													
	Peak Duration, min/day	0.1	0.1													
WEIGHT																
	Organisms and Cages, kg (lb)			*10* (22)	*20* (44)	1 (2.2)		5 (11)	*10* (22)			*20* (44)	40 (88)			
	Ancillary Research Equipment, kg (lb)			10 (22)	20 (44)	1 (2.2)		5 (11)	10 (22)			5 (11)	10 (22)			
VOLUME																
	Organisms and Cages, m^3 (ft^3)			0.25 (8.8)	0.50 (17.6)	0.02 (0.7)		0.15 (5.3)	0.30 (10.6)			0.2 (7)	0.4 (14)			
	Ancillary Research Equipment, m^3 (ft^3)			0.01 (0.35)	0.02 (0.7)	0.02 (0.7)		0.01 (0.35)	0.02 (0.7)			0.1 (3.5)	0.1 (3.5)			
LOGISTICS																
	Weight at Launch, kg (lb)			70 (154)	140 (308)	3 (6.6)		35 (77)	70 (154)			45 (99)	90 (198)			
	Supplies/Mo. Up, kg (lb)			50 (110)	100 (220)	1 (2.2)		25 (55)	50 (110)			20 (44)	40 (88)			
	Supplies/Mo. Down, kg (lb)			40 (88)	80 (176)	0.8 (2)		20 (44)	40 (88)			16 (35)	32 (70)			
	Weight at Termination, kg (lb)			70 (154)	140 (308)	2 (4.4)		35 (77)	70 (154)			40 (88)	80 (176)			
	Volume at Launch, m^3 (ft^3)			0.31 (11)	0.62 (22)	0.04 (1.4)		0.18 (6.4)	0.36 (12.7)			0.3 (11)	0.5 (18)			
	Supplies/Mo. Up, m^3 (ft^3)			0.05 (1.8)	0.10 (3.5)	0.02 (0.7)		0.03 (1.1)	0.06 (2)			0.1 (3.5)	0.2 (7)			
	Supplies/Mo. Down, m^3 (ft^3)			0.04 (1.4)	0.08 (2.8)	0.01 (0.35)		0.02 (0.7)	0.05 (1.8)			0.08 (2.8)	0.16 (5.6)			
	Volume at Termination															
	Frozen Specimens Down															
	Live Organisms Up	X	X	X	X	X		X	X			X	X			
	Live Organisms Down	X	X	X	X	X		X	X							
	Frozen Specimens Up															
	Other															
COMMUNICATIONS																
	Voice, hr/day	TBD										TBD	TBD			
	TV, B&W, hr/day	X										X	X			
	TV, Color, Ad Hoc	X										X	X			

2.4.3.1.4 Interface, Support and Performance Requirements

a. Envelope: 50 x 50 x 180 cm (20 x 20 x 72 in.)

b. Weight: 70 kg (154 lb)

c. Power: 27.5 ± 2.5 V dc, ± 5.5 ± 0.5 V dc, and ± 15 V dc. Approximately 7 watts continuous are required, with 52 watts additional (peak) for 5 minutes each day for controls, instrumentation, and data transmission. Maximum cumulative power is 59 watts.

d. Data requirements: Housekeeping, PCM 64 bits, water temperature, pressure, oxygen tension, hydrogen ion concentration.

2.4.3.1.5 Potential Role of Man. Man will initiate and terminate the experiment. If cinephotography is employed, man will change film cartridges, process, and edit for relay to ground. He will feed the fish, and will adjust the oscillatory period and amplitude.

2.4.3.1.6 Available Background Data. A Bioscience Experiment Survey Program proposal was abstracted for this experiment. Some prior investigations have been reported in the space science literature.

2.4.3.2 Vestibular Apparatus Development. The objective of this experiment is to determine if exposure to a non-1-g environment causes changes in semicircular canal function.

2.4.3.3 Neural Correlates of Function of the Mammalian Vestibular System. The objective of this experiment is to study the morphological effects of prolonged sensory deprivation (i.e., weightlessness) on development and maturation of the vestibular neuro-epithelium primary and secondary neurons of mammals born in zero gravitation. The hypothesis is that lack of appropriate sensory stimulation of a specialized receptor such as the eye in newborn animals leads to structural and subsequent functional changes in the primary, secondary, and tertiary levels of the visual system.

2.4.3.4 Effects of Changes in Gravity on the Otolith. This experiment's objective is to find out whether the receptor organ for gravity is altered when gravity itself is changed.

2.4.3.5 Neural and Behavioral Development in Inbred Mice. Will mice subjected to weightlessness during a major portion of their organogenesis show morphological changes in their nervous system and disturbances in behavior?

2.4.3.6 Force of Isometric Contraction of Non-Vestibular/Vestibular Muscle in Low-Gravity Environments. Determine whether muscle systems are biased for a 1-g environment, with those systems receiving direct vestibular input showing a greater dysfunction in a hypogravity environment than non-vestibular muscle systems.

2.5 FPE INTERFACE, SUPPORT AND PERFORMANCE REQUIREMENTS

The summary data presented in Table 2-11 represents, in the best judgment of NASA scientists, the overall facility and experimental requirements to accomplish a realistic experimental program, and is based on some projection of the state of the art. The rationale for selection of the summary parameters is in some instances arbitrary but has as a basis the total NASA experience and knowledge gained from prior flight, experiment definition, and integration programs. The basis for each data entry is given in the notes.

2.6 POTENTIAL MODE OF OPERATION

With regard to the specific Mode A, limited on-orbit stay time as with Space Shuttle, there are some experiments of less than 30 days duration which can be accommodated by this mode; but there are other experiments which require more than 30 days and cannot be accommodated. As for Mode B, extended on-orbit stay time, unmanned, with periodic revisits by Space Shuttle, there are some experiments which can be automated for accommodation by this mode, but the interval between crew visits should not exceed 30 days and a shorter interval such as 15 days is much preferred. Some experiments require Mode C, extended on-orbit stay time with Space Station, and this is the preferred mode for all experiments of this FPE.

2.7 ROLE OF MAN

Based on all activities in all experiments, man may potentially carry out the functions itemized below. In a high-load day in which contingencies call for the absolute maximum effort, the crew may be required to devote 14 or more hours to experiment manipulations. These occasions will be infrequent, occurring mainly at experiment setup and termination times. In contrast with a fixed load on a minimum-effort day, considering only housekeeping and colony management, the scientist may be committed to as little as two hours' time, leaving him free for creative activities such as onboard data reduction and interpretation and planning of new and follow-on experiments. The average day, including housekeeping plus ad hoc research activities, will be six to eight hours long.

a. Routine tasks (all experiments)

 1. Laboratory housekeeping, maintenance and repair
 2. Experiment setup
 3. Monitor organisms, hardware and data
 4. Experiment termination
 5. Specimen preparation for logistics return; package experiments, samples, photographs and other records for return to earth.

Table 2-11. Vertebrate Research Facility (FPE Summary Data)

Weight, kg (lb)	1063 (2345)	Note 1
Volume, m^3 (ft^3)	38 (1340)	Note 1
Power, watts	4070	Note 2
Crew Skills		
1. Biological Technician 2. Microbiological Technician 3. Biochemist 4. Physiologist 12. Electromechanical Technician 22. Chemical Technician		
Data Rate, bps	1095	Note 2
Analog Data: hours/day frequency, MHz	4.2 4	
Logistics Up, 30-day average, kg (lb)	262 (578)	Note 3
Logistics Down, 30-day average, kg (lb)		
1st 2 years	196 (433)	Note 4
3rd year on	236 (520)	Note 5
Pointing and Stabilization	NA	
Orbit Altitude and Inclination	NA	
Unique Environment Requirements	Isolation from rhythmic phenomena, noise, vibration. Possibly require isolation from EMI and ESI. Acceleration allowable at holding unit $< 10^{-3}$ g.	

NOTES:

1: CORE units + FPE units + two logistic cycles of expendables + one complement of test subjects. Radiobiology unit and bioresearch centrifuge not included.
2: 40% of CORE units total + 75% of FPE units total = normal load.
3: 1% of FPE units + 80% of expendables to support total specimen holding capability + 16-2/3% specimen complement (equivalent to 50% replacement of specimens every 90 days).
4: 75% of logistics up.
5: 90% of logistics up.

b. Experiment-peculiar research activities (desirable to enhance scientific value and responsiveness of experiment, but not critical to successful execution of basic experiment).

1. Set up follow-on experiments with tissue from prior experiments, onboard organisms, and newly arrived organisms
2. Common lab techniques, e.g., mass measurement, fluid handling
3. Perform laboratory analysis; biochemistries
4. Gross morphological examination
5. Cytological and histological preparations and preliminary analysis
6. Programmed and ad hoc photography at request of P.I.
7. Ad hoc TV monitoring in conference with P.I.
8. Install and operate plate physiological and metabolic instrumentation, etc.
9. Radiobiology techniques; administer and detect isotopic tracers
10. Collect and preserve whole specimens
11. Dissect and freeze specimens with dry ice or LN_2.

2.8 SCHEDULES

Estimates of the development time for the experiments described in this FPE are shown in Table 2-12.

2.9 PRELAUNCH SUPPORT AND GSE

A common-use Life Sciences laboratory is required at the launch area to support the experiment packages and, in most cases, maintain sterility. It is suggested that this facility be sufficiently comprehensive to allow all the Principal Investigators and their research team to do all final assemblies and preparations.

A Life Sciences general ground control facility is required to provide a delayed simulation of the space bioresearch lab in terms of radiation, vibration, atmospheric composition, and man involvement. An optimum design is a duplicate facility of the space bioresearch lab, supported by the necessary radiation sources, mechanical actuation, and bottle-gas inventory, operated on the ground for all biological control. Separation of the FPEs in the control facility can introduce additional variables.

The launch preparation facility and the ground control facility should be in the same complex. A direct link to mission control would provide communication with the space lab and the control facility and members of the experiment research staff.

Table 2-12. Development Time Schedules

	1	2	3	4	5	YEARS
2.4.1.1 Orbiting Subhuman Primate	———	———	———	———	———	
2.4.1.2 Cardiovascular Adaptation During Long-Term Weightlessness	———	———	———	———		
2.4.1.3 Effects of Reduced Gravity on Bioelectric Potentials and Bone Metabolism	———	———	———			
2.4.1.4 Immune Response of Animals	———	———	———			
2.4.1.5 Tissue and Cell Morphology with and Without Endocrine Gland Ablations	———	———	———			
2.4.1.6 Tissue Growth and Repair and Weightlessness	———	———	———			
2.4.2.1 Role of Gravity in the Life Processes of Mammals	———	———	———	———		
2.4.2.2 Necessity of Gravity for Normal Growth of Turtles	———	———	———			
2.4.2.3 Weightlessness, Growth and Rhythms	———	———	———			
2.4.2.4 Effect of Weightlessness on Chickens	———	———	———	———		
2.4.2.5 Circadian Rhythms	———	———				
2.4.2.6 Central Nervous System Function in Hibernating or Hypothermic Mammals in Weightlessness	———	———	———			
2.4.2.7 Role of Gravity in Avian Bone Metabolism	———	———	———	———		
2.4.3.1 Vestibular Research in Space	———	———				
2.4.3.2 Vestibular Apparatus Development	———	———	———			
2.4.3.3 Neural Correlates of Function of the Mammalian Vestibular System	———	———	———			
2.4.3.4 Effects of Changes in Gravity on the Otolith	———	———	———			
2.4.3.5 Neural and Behavioral Development in Inbred Mice	———	———	———			
2.4.3.6 Force of Isometric Contraction of Non-Vestibular/Vestibular Muscle in Low-Gravity Environments	———	———	———			

2.10 SAFETY ANALYSIS

Safety hazards and precautions to be observed are shown in Table 2-13.

Table 2-13. Safety Analysis

Hazards	Precautions
Animal Cages	
Exposure to cage atmosphere	Cage-open operation performed in hooded work bench.
	Slight ΔP into cage.
Leaks from disconnects during cage removal.	Purge capability
	Adequate contaminant removal system.
	Air flow adequate to move and trap free particles and debris.
	Vacuum cleaner to collect and remove free particles and debris.
Overpressurization of cage rack.	Pressure relief valve
Experiment Procedures	
Chemical exposure	Work in hooded work area.
	Purge capability.
	Use unbreakable containers.
	Inert atmosphere.
	Store in hermetically sealed cabinet, which is purgable.
	Emergency life support.
Debris exposure	Work in hooded work area.
	Adequate air flow to EC/LS.
	Emergency debris mask.
Cryogenic spillage	Inert atmosphere.
	Purging capability.
	Emergency life support.

Table 2-13. Safety Analysis, Contd

Hazards	Precautions
Feces - Storage exposure during experiment by-products management, waste processing, etc.	Store in sealed plastic bags after each collection.
Atmosphere Contamination	
Microbiological	Overgarments
	Catalytic burner
Debris	Filters
	Laminar flow branch
Chemical	Vacuum cleaner
	Washing
	UV irradiation
	Air lock
Animal Cage Rack Contamination	Sterilization
Specimen Return/Exchange	Overgarment bag

2.11 AVAILABLE BACKGROUND DATA

The experiment data has been provided by NASA Ames Research Center. The data is based on proprietary proposals received by NASA from Principal Investigators. The proposal data has been modified in some cases to fit the greater mission model provided by a general manned bioresearch laboratory as compared to Biosatellite missions.

a. AIBS - Bioscience Research During Earth-Orbiting Missions: 1967 Regional council studies in all disciplines.

b. Study of an Animal Research Facility for a Manned Orbital Biotech Lab., Sept. 1967.

c. Experiment Implementation Plan for Manned Space Flight Experiments.

d. Biomedical Program for Extended Space Missions.

e. MDAC

f. The Automated Primate Research Laboratory, UC Berkeley.

g. Orbiting Experiments for Study of Extended Weightlessness, (2 Primates, 1 year) Northrop.

h. Earth Orbital Experiments Program and Requirements Study, NASA/MDAC, 1971.

VOLUME VIII

SECTION 3

PLANT RESEARCH FACILITY

SECTION 3

PLANT RESEARCH FACILITY

3.1 GOALS AND OBJECTIVES

The goals and objectives of this FPE are to define the support and operational requirements of an orbital research facility in which a broad research program can be carried out in pursuit of the goals and objectives of the space biology program.

The research program covers the effects of space environment (weightlessness, subgravity, ionizing radiation, etc.) on all major aspects of plant biochemistry, physiology, and genetics. Particular emphasis is placed on morphology, growth, development, maturation, longevity, reproduction, and cyclic phenomena.

3.2 PHYSICAL DESCRIPTION

The Plant Research Facility includes all of the CORE units in addition to the plant growing and holding facility, radiobiology unit, bioresearch centrifuge, and specimen return unit. The facility concept is illustrated in Figure 3-1.

Plants will be grown through successive generations for studies on reproduction, longevity and genetics. The growing and holding facility must therefore be adequate to propagate a wide variety of plants over extended periods of time. Approximately TBD m^3 (TBD ft^3) comprising TBD m^3 (TBD ft^3) of "greenhouse" space is required. Specific plant types and environmental requirements are detailed in Section 3.4.

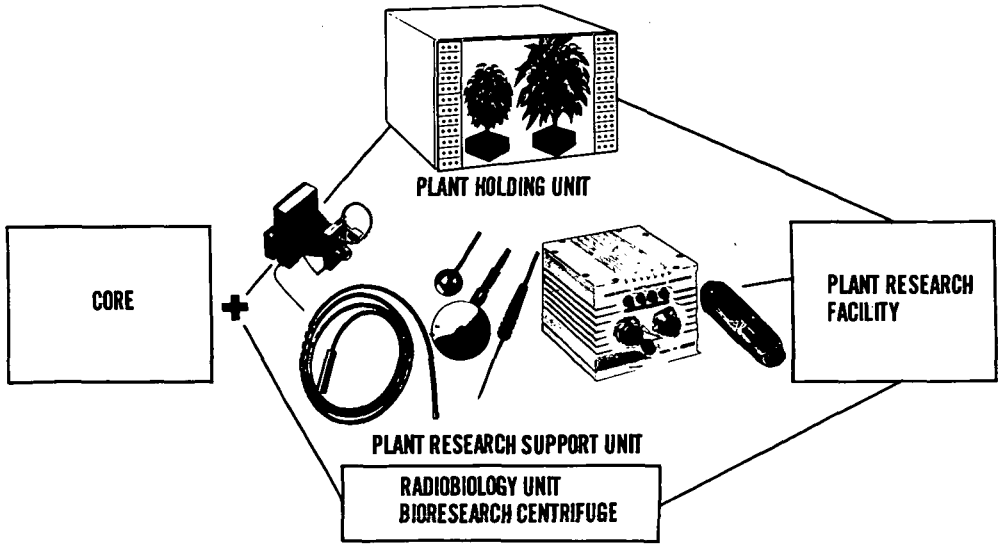


Figure 3-1. Life Sciences Plant Research Facility

As in the preceding FPEs, this is not an "all-or-none" requirement; operations and scheduling will be based upon mission characteristics, available technology, etc.

3.2.1 PLANT RESEARCH SUPPORT UNIT

3.2.1.1 Functional Capability. This unit contains the specific equipment for:

a. Plant lighting.

b. Photo/TV coverage of plants.

c. Time identification.

d. Specimen identification.

e. Specific ion analysis.

f. Growth measurements.

g. Activity measurements.

h. Water and nutrients management.

i. Water and nutrients sampling.

j. Event verification.

k. Clinostat.

3.2.1.2 Description. The facility consists of equipment and equipment accessories required for plant research. Many items require specific storage due to their delicate nature. Observation/measurement transducers specific to plants defined here are supported by the electronic plug-in modules from the Data Management equipment unit in the CORE. Power to operate these plug-ins is averaged into the plant holding unit requirements. Power for lighting and for the electromechanical actuators required for many tasks is also averaged into the holding unit power.

Table 3-1 lists the equipment in this unit, and Table 3-2 is the equipment unit summary.

3.2.2 PLANT HOLDING UNIT

3.2.2.1 Functional Capability. Houses a wide variety of plants from microscopic specimens to plants 20 cm tall, and provides a range of environmental requirements for plant research.

3.2.2.2 Description. The plants will be housed in standardized plant maintenance and growth modules, such as the cage rack system for vertebrate holding, measuring 65 x 65 x 40 cm (25.6 x 25.6 x 15.7 in.) with general data and ECS support. Plant holding modules will contain a rack and module system standardized with the other

Table 3-1. Plant Research Support Unit Equipment List

NAME	PERFORMANCE CHARACTERISTICS	POWER W	WEIGHT kg (lb)	VOLUME m^3 (ft^3)	OTHER OR REMARKS
Plant Lighting System	Daylight-fluorescent lights 1100 lum/m^2 (102 ft-c). Heat management from lights.	25	1 (2.2)	0.04 (1.4)	Power, weight, and volume per package; 9 packages required in lab and 9 in centrifuge.
Photo/TV Accessories	Hardware support and commutation over specimen groups.	2	0.5 (1.1)	0.0003 (0.01)	Need 9 in lab and 9 in centrifuge.
Clock and Timer	Event timing; photo/TV timer identification.	1	0.2 (0.44)	0.0003 (0.01)	Need 9 in lab and 9 in centrifuge.
Rack and Cabinet System	To store plant hardware.	0	45 (99)	1.0 (35)	Must accommodate listed items plus all new experiment-specific hardware.
Growth and Support Containers (pots)	Various sizes to support seedlings to 20-cm plants.	0	5 (11)	0.06 (2.1)	
Miscellaneous Tools and Hardware for Plant Research		0	10 (22)	0.12 (4.2)	

Table 3-2. Equipment Unit Summary

	Laboratory Only	Laboratory + Centrifuge
OPERATOR SKILL	TBD	TBD
POWER, AC		
average, watts	0	0
peak, watts	0	0
peak duration, hr/day	0	0
POWER, DC		
average, watts	250	500
peak, watts	250	500
peak duration, hr/day	24	24
WEIGHT, kg (lb)	70 (154)	75 (165)
ENVELOPE		
volume, m^3 (ft^3)	1.5 (53)	1.7 (60)
height, cm (in.)	TBD	TBD
width or diam. cm (in.)	TBD	TBD
depth, cm (in.)	TBD	TBD
DATA		
voice, hr/day	TBD	TBD
TV, B&W, hr/day		
TV, color, hr/day		
analog, MHz	TBD	TBD
digital, bps	TBD	TBD

FPE holding units for the data management electronic plug-ins, and will be consistent with the manifolding system for electronics, pneumatics and hydraulics.

The Plant Holding Unit specifications are:

a. Temperature — Precision ± 1° K. of setting, 293 to 313° K (20-40° C).

b. Relative Humidity — Precision ± 5% of setting. Range 40-90%.

c.	Atmospheric Pressure	760 ± 20 mm. Hg.
d.	pO_2	150 ± 10 mm. Hg.
e.	pCO_2	3.9 ± 3.7 mm. Hg.
f.	Ethylene	Less than TBD
g.	Lighting	Daylight fluorescent, 1100 lum/m^2 (102 ft-C)
h.	Light/Dark Cycle	0 - 100%

Atmospheric isolation is not required, but temperature of incoming air from spacecraft must be controlled within ± 1° K. Noise isolation is required if noise level will exceed 130 dB at any time (e.g., at launch or reentry). Vibration isolation is by shock-absorbing mountings. Gravity level in orbit is 10^{-5} g or less for 95% of time, and not more than 10^{-3} g during spacecraft maneuvers.

Noncyclical temperature variations must be within allowable range. There shall be no direct air impingement on experiment package or any portion thereof, or on any specimen within package. No contaminants are allowable within the package encasement. No periodic cues shall occur at whole-number fractions of 24 hours.

The number of plant holding units required for the maximum plant facility is dependent on the following assumptions:

a. Statistical requirements: N = 32 for large-number statistics; n = 10 for small-number statistics.

b. Variables (gravity): Zero-g and two levels of artificial g.

c. Average plant size: 10 x 10 x 25 cm (4 x 4 x 10 in.).

d. Two experiments simultaneously.

Using the cage-rack system as a model, the lab-only requirements are 9 cage racks; the lab plus centrifuge requires 18 cage racks.

Table 3-3 lists equipment for the Plant Holding Unit. Table 3-4 is the equipment-unit summary.

3.3 EXPERIMENT REQUIREMENTS SUMMARY

Refer to Experiment Classes in Section 3.4.

3.4 EXPERIMENT PROGRAM

The plant research program is comprised of a group of representative experiment classes, each supported by a group of representative experiments. Within each class,

Table 3-3. Plant Holding Unit Equipment List

NAME	PERFORMANCE CHARACTERISTICS	POWER W	WEIGHT kg (lb)	VOLUME m^3 (ft^3)
Plant holding units	Lab-only requirements (9) Lab plus Centrifuge (18)	10 ea.	30 (66) ea.	0.16 (5.6) ea.
Rack and Manifold System	To physically support holding units.	TBD	TBD	TBD

the first of the representative experiments is described in detail; other representative experiments are given by title and experiment requirements data only. These selected representative experiments provide experiment support requirements and other spacecraft and mission impacts to a level which is ample to characterize the requisite Plant Research Facility. Table 3-5 enumerates the representative experiment classes and representative experiments which scope the experiment program.

3.4.1 ROLE OF GRAVITY IN PLANT LIFE CYCLES AND PROCESSES. The fundamental objective of this experiment class is to determine the role gravity plays in the life cycle and processes of plants. The study is based on the hypothesis that in weightlessness, processes of basic plant metabolism will be altered and the plants will develop morphological similarities to, but physiological and biochemical differences from, plants grown on the clinostat – a gravity compensating device used to simulate hypogravity. An experiment requirements summary is shown in Table 3-6.

3.4.1.1 Metabolism and Energetics in Hypogravity

3.4.1.1.1 Scientific Objective. The objective of this experiment is to conduct an in-depth study of the hypogravitational and ambient particulate radiation effects of Earth-orbital flight on the physiological, biochemical, and morphological changes in one species of plant.

3.4.1.1.2 Description. Significant areas of major metabolic pathways will be investigated by a consortium of competent scientists in the field of plant physiology, biochemistry, histology, enzymology, photosynthesis, anatomy and radiation. This team approach will permit a comprehensive study most effectively, efficiently and economically. To acquire the maximum data from the experiment, one plant species (e.g., Tagetes minutum) will be used by all the investigators. This will permit coordination of conclusions and avoidance of inevitable controversies which ensue from the use of different species and different flight conditions. By utilizing the one species, sources of experimental error will be minimized and controls can be rigidly and consistently maintained. The experimental environment will be programmed and monitored to

Table 3-4. Equipment Unit Summary

	Laboratory Only	Laboratory + Centrifuge
OPERATOR SKILL	TBD	TBD
POWER, AC		
average, watts	90	180
peak, watts	90	180
peak duration, hr/day	24	24
POWER, DC		
average, watts	TBD	TBD
peak, watts	TBD	TBD
peak duration, hr/day	TBD	TBD
WEIGHT, kg (lb)	270 (595)	540 (1190)
ENVELOPE		
volume, m^3 (ft^3)	1.5 (53)	3 (106)
height, cm (in.)	TBD	TBD
width or diam. cm (in.)	TBD	TBD
depth, cm (in.)	TBD	TBD
DATA		
voice, hr/day	TBD	TBD
TV, B&W, hr/day		
TV, color, hr/day		
analog, MHz	3 hr/day	3 hr/day
digital, bps	925	925

minimize variables other than gravity and ambient particulate radiation. A central, flight-experienced directing group will aid in the coordination of each individual phase of the project and maintain a uniformly smooth functioning operation.

The dwarf marigold (Tagetes minutum) will be used, since it is relatively small, completes a life cycle in 30 days, and responds with epinasty to growth on a horizontal clinostat. The growth medium will be vermiculite-like material, containing proper nutrients.

Table 3-5. Plant Research Program

Section	Title	Detailed Experiment Description	Title & Data Only
3.4.1	Experiment Class: Role of Gravity in Plant Life Cycles and Processes	-	-
3.4.1.1	Experiment: Metabolism and energetics in hypogravity	X	
3.4.1.2	Experiment: Plant growth at low-g level		X
3.4.1.3	Experiment: Orbital growth of dicotyledenous seedlings		X
3.4.1.4	Experiment: Biochemical and biorhythmic changes in plants due to reduced gravity		X
3.4.1.5	Experiment: Effects of weightlessness on gametogenesis and morphogenesis in gametophytes		X
3.4.2	Experiment Class: Graviception and Tropisms	-	-
3.4.2.1	Experiment: Physiological response of plants to a hypogravity-gradient environment	X	
3.4.2.2	Experiment: Growth transients in roots exposed to a weightless environment		X
3.4.3	Experiment Class: Effects of the Space Environment on Plant Genetics	-	-
3.4.3.1	Experiment: Low-g effects on Tradescantia	X	
3.4.3.2	Experiment: Effects of UV irradiation on mitotic recombination in weightlessness		X

Table 3-6. Experiment Requirements Summary

EXPERIMENT NO. AND TITLE	3411 Metabolism and Energetics in Hypogravity		3412 Plant Growth at Low-g Level		3413 Orbital Growth of Dicotyledonous Seedlings		3414 Biochemical & Biorhythmic Changes in Plants Due to Reduced Gravity		3415 Effects of Weightlessness on Gamatogenesis & Morphogenesis in Gametophytes						NOTES
SPECIMEN	Dwarf Marigold Tagetes Minutum		Arabidopsis		Garden Pea		Bean Vigna Sinensis		Pteris Gametophytes						
LOCATION	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	
NO. OF SPECIMENS	32	64													
HOLDING CAGES															[1] No periodic cues at whole-number fractions of 24 hours.
Standard	32 pots	64 pots							Honey Comb Pkg	Honey Comb Pkg					
Metabolic															[2] Normal Laboratory Max.: 10^{-3} 90% of time; 10^{-2} 10% of time
Colony															
MAN REQUIREMENTS, hr															
Skill 1															
Setup	4	8					0.5	1							
Daily Average [3]	1	2					-	-							
Terminate	4	8					0.5	1							
Skill 3															[3] Ad Hoc observations are required up to 8 hr/day. They cannot be scheduled and are part of the daily average. Crew time is average.
Setup															
Daily Average [3]															
Terminate															
Skill 4															[4] SMAC = Space maximum allowable concentration for man.
Setup															
Daily Average [3]															
Terminate															
EXPERIMENT DURATION, days	35 20-150	35 20-150	21	21					70 to 300	70 to 300					[5] No offensive or noxious odors.
ENVIRONMENTAL REQMTS															[6] TBD; minimal to reasonable engineering design.
pO_2, mm Hg	150±10	150±10					150±10	150±10	150±10	150±10					
Total Pressure, mm Hg	760±10	760±10	760±10	760±10	760±10	760±10	760±10	760±10	760±10	760±10					[7] Arterial & Venous
pCO_2, mm Hg	0.2-7.6	0.2-7.6			<7.6	<7.6	3.8	3.8	3.8	3.8					
pCO, mm Hg															[8] Includes blood, feces, urine, bacterial, gas, and biopsy samples.
pNH_3, mm Hg															
H_2O, mm Hg	13-18	13-18					13-18	13-18	13-20	13-20					
Temperature, °K (°C)	(24±1) 297±1	(24±1) 297±1	(25±1) 298±1	(25±1) 298±1	(20±2) 293±2	(20±2) 293±2	(24±.8) 297±.8	(24±.8) 297±.8	(24±3) 297±3	(24±3) 297±3					[9] Samples per week/tests per sample
O_2 Uptake, kg day															
CO_2, kg day															[10] Measurements made at holding unit level only; () = each organism.
Noise, dB	<130	<130	[6]	[6]					<120	<120					
Vibration	[6]	[6]	[6]	[6]					[6]	[6]					
Acceleration, g	[11]	0.5 & 1g	[11]	0.1 & 1g	[11]	1g	[11]	1g	[11]	1g					[11] 10^{-5} 90% of time; not greater than 10^{-3} during spacecraft maneuvers.
Radiation	[6]	[6]	[6]	[6]					[6]	[6]					
Illumination, lum/m^2 (ft-c)	(100±10) 1080±100	(100±10) 1080±100					(100±10) 1080±100	(100±10) 1080±100	(100±10) 1080±100	(100±10) 1080±100					
Trace Contaminants	[4]	[4]													
NUMBER AND FREQUENCY OF MEASUREMENTS															

Table 3-6. Experiment Requirements Summary, Contd

EXPERIMENT NO.		3411		3412		3413		3414		3415						
LOCATION		Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	NOTES
NUMBER AND FREQUENCY OF MEASUREMENTS	Number and Frequency of Measurements															
	pO_2, hourly [10]	X	X	X	X					X	X					
	pCO_2, hourly [10]	X	X	X	X					X	X					
	pNH_3, hourly [10]	X	X	X	X											
	pH_2O, hourly [10]	X	X	X	X					X	X					
	Temp., hourly [10]	X	X	X	X	X ea ½hr	X ea ½hr	X	X	X	X					
	Noise, continuous [10]	X	X	X	X					X	X					
	Vibration, cont. [10]	X	X	X	X					X	X					
	Acceleration, cont. [10]	X	X	X	X					X	X					
	Radiation, cont. [10]	X	X	X	X					X	X					
	Organism Sacrifice/wk															
	Urine Analysis/wk															
	Organism Visual Monitorings/wk															
	Organism Recovery Preparation, No.															
	Organism Live Recovery, No.															
	Illumination, No./meas.															
	Radiobiologies/wk															
	Total Pressure, hrly [10]	X	X	X	X					X	X					
	Event Verification No/day	X	X	X	X	X	X									
	Illumination	X	X	X	X	X	X	X	X	X	X					
	Leaf Movement	X	X					X	X							
	Biochemistries							X	X							
	Specimen Fixation	X	X	X	X	X	X	X	X							
	Contamination Msmts/day [10]	X	X	X	X	X	X	X	X	X	X					
POWER																OTHER
AC																
	Continuous, watts															
	Peak, watts															
	Peak Duration, min/day															
DC																
	Continuous, watts	25	50	120	240	30	60	35	70	6	6					
	Peak, watts					80	160									
	Peak Duration, min/day															
WEIGHT																
	Organisms and Cages, kg (lb)	20 (44)	40 (88)	40 (88)	80 (176)			(20)	(40)	2.7 (6)	5.4					
	Ancillary Research Equipment, kg (lb)	1 (2.2)	1 (2.2)	1 (2.2)	1 (2.2)			1 (2.2)	1 (2.2)	0.5	1 (2.2)					
VOLUME																
	Organisms and Cages, m^3 (ft^3)	0.2 (7)	0.4 (14)	0.14 (10)	0.28 (20)			0.03 (1)	0.06 (2)	0.01 (.35)	0.01 (.35)					
	Ancillary Research Equipment, m^3 (ft^3)	0.01 (0.35)	0.01 (0.35)	0.01 (0.35)	0.01 (0.35)			0.01 (0.35)	0.01 (0.35)	0.01 (0.35)	0.01 (0.35)					
LOGISTICS																
	Weight at Launch, kg (lb)	21 (46.2)	41 (90)	41 (90)	81 (178)			10 (22.2)	20 (42.2)	3.2 (7)	5.5 (12.1)					
	Supplies/Mo. Up, kg (lb)	-	-	-	-			-	-							
	Supplies/Mo. Down, kg (lb)	-	-	-	-			-	-	-						
	Weight at Termination, kg (lb)	20 (44)	40 (88)	40 (88)	80 (176)			22 (22)	42 (42)	3 (6.6)	5 (12.1)					
	Volume at Launch, m^3 (ft^3)	0.21 (7.4)	0.41 (14.5)	0.15 (5.3)	0.30 (10.6)			0.04 (1.4)	0.07 (2.5)	0.02 0.7	0.02 0.7					
	Supplies/Mo. Up, m^3 (ft^3)	-	-	-												
	Supplies/Mo. Down, m^3 (ft^3)	-	-	-												
	Volume at Termination	21	0.41	0.15	0.30			0.04	0.07	0.51	1.0					
	Frozen Specimens Down	X	X													
	Live Organisms Up	X	X	X	X			X	X	X	X					
	Live Organisms Down	X	X					X	X	X	X					
	Frozen Specimens Up															
	Other Film	X	X	X	X	X	X	X	X	X	X					
COMMUNICATIONS																
	Voice, hr/day	TBD	TBD	TBD	TBD											
	TV, B&W	X	X	X	X					X	X					
	TV, Color, Ad Hoc	X	X	X	X					X	X					

The experiment will consist of seven sub-experiments, each to be performed in a separate module under the following conditions:

a. Modules I, II, and III – Seedlings; day/night lighting (16/8 hr.); fixation or freeze-drying after 10, 20 and 30 days, respectively; the 30-day module to be used for gas-exchange analysis.

b. Module IV – Seeds germinated and grown in space; continuous lighting from 5th day to post-flight lab; time-lapse photography every 30 min from 5th day to post-flight lab.

c. Module V – Seedlings; continuous lighting; no treatment of plants.

d. Module VI – Seedlings; continuous lighting except for dark treatment periods.

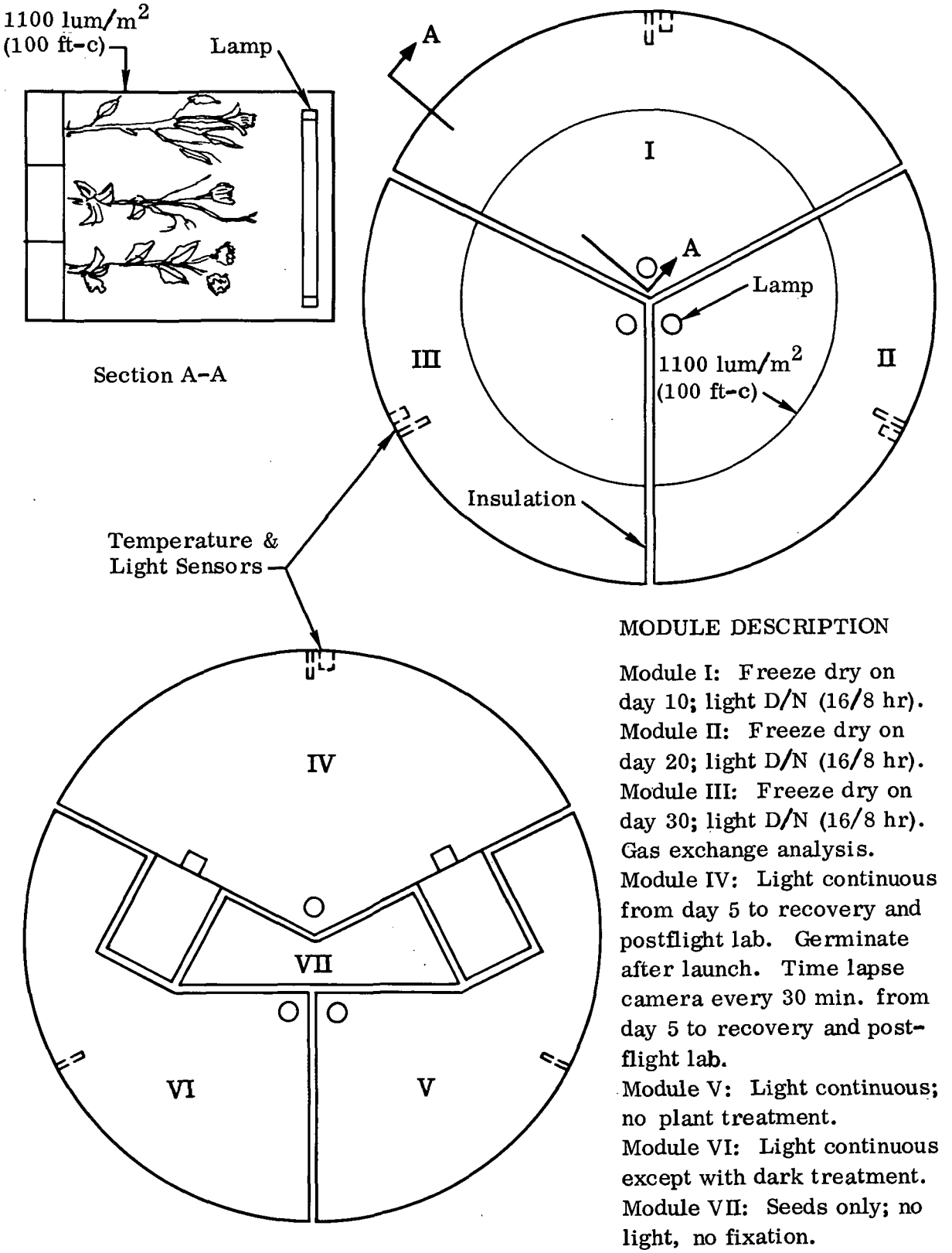
e. Module VII – Seeds; no light or fixation.

Each sub-experiment module will contain a minimum of either 32 seeds or 32 plants (grown from either seeds or seedlings) and one or more packets of single-layered seeds (100 seeds per packet) sandwiched firmly in appropriate grooves between two thin layers of plastic dosimeters for analyzing the tracks and size (Z number) of ionizing particles.

The seven sub-experiment modules will comprise an experimental package (see Figures 3-2 and 3-3 for sketches of arrangements); there will be eight such packages. Three of these will be used for flight – one to be flown in the weightless environment, one to be flown under 1 g in the onboard biocentrifuge, and one for backup. These packages will be acceptance tested and bioconditioned for flight. The remaining five packages, which can be the prototypes, will be used for ground controls – clinostats, centrifuge (1 g), upright, and stationary. The performance capability of each package will be a minimum of 35 days and a maximum of 150 days.

Both seeds and plant seedlings will be launched in the appropriate modules. Seeds in Module IV will be germinated by imbibition of water in orbit when steady hypogravity has been attained. Seeds in Module VII will be flown dormant and recovered following scheduled flight for subsequent sowing and study on the ground. Seedlings in the remainder of the modules will be treated as described earlier. Some plants will be allowed to bear seeds; others will be fixed either chemically or cryogenically during various phases of development. Both seeds and plants, fresh as well as preserved, will be recovered for analyses as described below. Schematics of typical experimental approaches are given in Figures 3-4 and 3-5.

The time duration for this flight is 35 days minimum and up to 150 days maximum. This specification is desired to ensure thorough adaptation to the hypogravitational environment and to permit the development and acquisition of viable seeds. Prolonged exposure will eliminate the effects of vibration and other traumas induced by launch. The conditions of temperature, gaseous concentration, humidity, light intensity,



MODULE DESCRIPTION

Module I: Freeze dry on day 10; light D/N (16/8 hr).
Module II: Freeze dry on day 20; light D/N (16/8 hr).
Module III: Freeze dry on day 30; light D/N (16/8 hr). Gas exchange analysis.
Module IV: Light continuous from day 5 to recovery and postflight lab. Germinate after launch. Time lapse camera every 30 min. from day 5 to recovery and post-flight lab.
Module V: Light continuous; no plant treatment.
Module VI: Light continuous except with dark treatment.
Module VII: Seeds only; no light, no fixation.

Figure 3-2. Experiment Packages

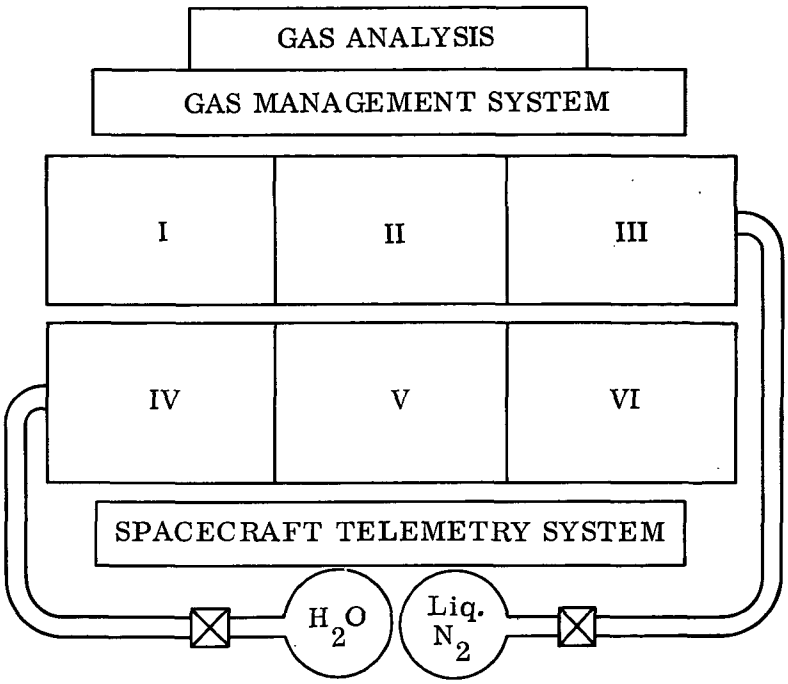


Figure 3-3. Schematic Drawing of Module

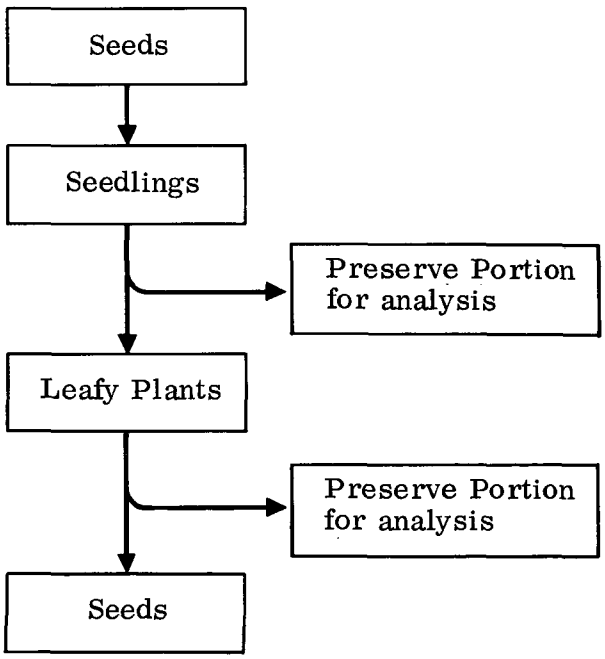


Figure 3-4. Experimental Logic for Producing F-2 Seeds While Preserving Specimen for Subsequent Biochemical Analysis

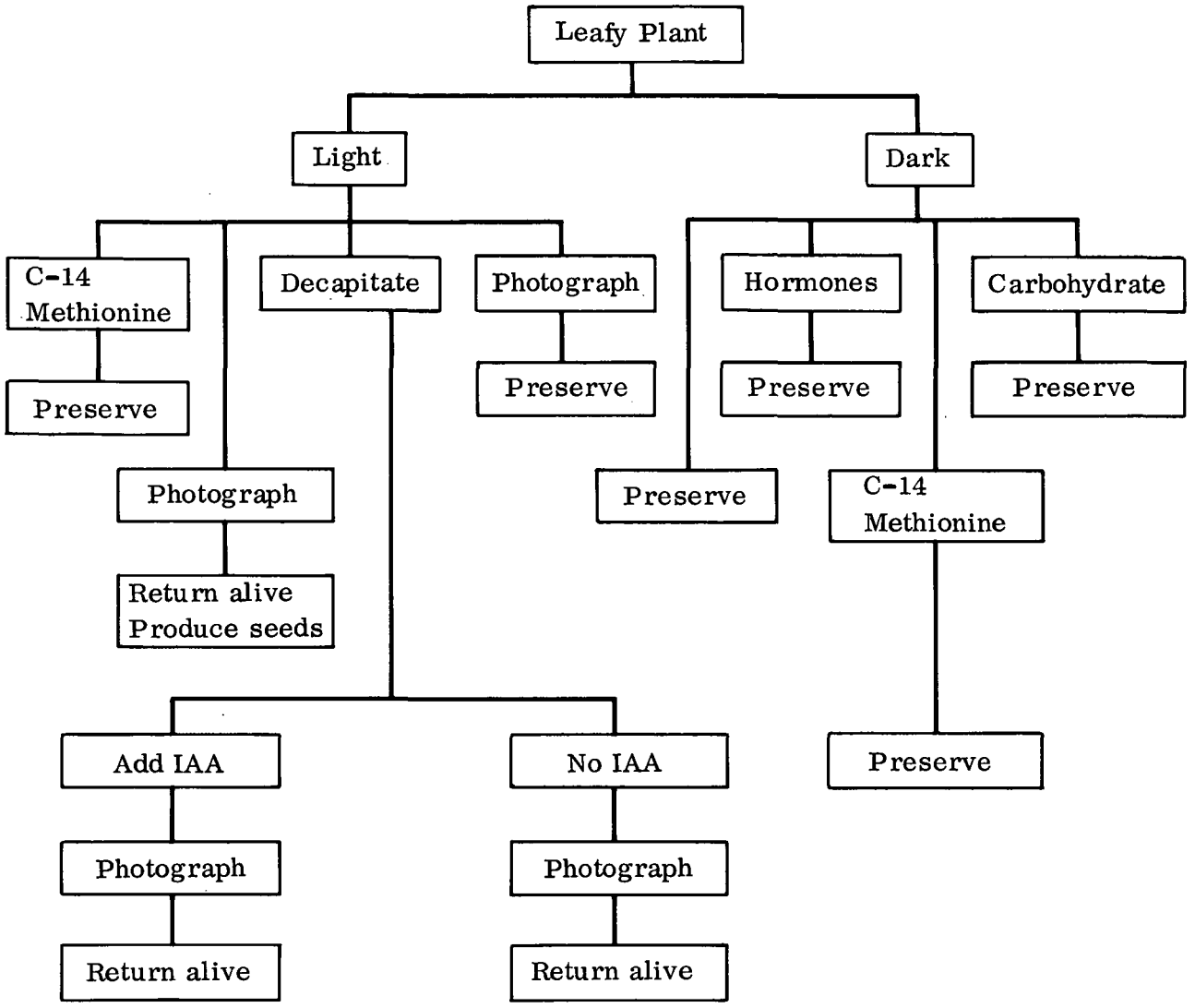


Figure 3-5. Logic Diagram Indicating Experimental Approach

airflow, and other important variables in the spacecraft will be maintained within the specifications required by the experiment. The onboard 1-g control and ground-control experiments will be programmed to exactly duplicate environmental conditions experienced by the hypogravity experiment specimens. Tests will be performed to assure that the biological specimens and their support hardware will survive the vibration and noise induced by stresses of launch, orbit, and recovery.

Upon recovery of the plant specimens, biochemical, histochemical, cytochemical, and morphological analyses will be initiated immediately to define and measure the biological aberrations induced by hypogravity and/or ambient particulate space radiation. The recovered seeds will be grown under controlled environmental conditions and various parameters of their germination and the developing plants will be investigated for several generations. The plastic radiation dosimeters will be examined and analyzed

to show the relation of particle track and size (Z number) to damage sites in each specimen.

While the above summary description is written for a fully automated experimental system capable of being flown in an unmanned Earth-orbiting vehicle or in a manned vehicle with little or no interphasing with onboard personnel, the experiment can be accomplished considerably more effectively and with significantly less developmental cost of equipment in a flight wherein man participates in the experiment. The degree to which a flight crew or an onboard investigator interphases with the experiment is quite flexible and can be varied according to available crew time as described in Section 3.4.1.1.5.

The following description of the facilities and equipment is written for a manned Earth-orbital flight in which man's participation is optimized.

The facilities and/or capabilities provided by the CORE will be used for the Plant Research Facility as follows:

a. The Visual Records and Microscopy Unit will provide the capability for taking still photographs, for time-lapse photography (or its equivalent) of plants in each of the seven sub-experiments, for recording observations visually and/or verbally, and for gross and/or microscopic examinations.

b. All plant sub-experiment modules will be coupled to the CORE Data Management Unit and the Life Sciences Support Unit for research programming command purposes (e.g., ECS cycling, etc.); management of environmental data readout such as temperature, humidity, gas composition (including build-up of toxic contaminants – e.g., ethylene), g-environment, etc., from each of the modules; recording and management of automated observations such as time-lapse photography, plant growth, and movements from strain gauges; and data acquisition of the bioenergetics, respirations, photosynthesis, biorhythmic movements, etc.

c. The plant specimens will be prepared for analyses or for preservation and storage for return to ground in the Preparation, Preservation and Retrieval Unit. Prepared specimens will be analyzed in the Biochemical and Biophysical Analysis Unit and/or the Visual Records and Microscopy Unit.

d. The Maintenance, Repair and Fabrication Unit will be used for checking out, adjusting, repairing and/or modifying sub-experiment modules, the Plant Housing Unit, analytical instruments, and other equipment.

e. FPE or experiment-peculiar equipment and/or instruments not in use will be stored in the Ancillary Storage Unit until subsequent need or for return to ground if a need is not foreseeable.

Additional facility/equipment requirements are:

a. Capability for onboard personnel to remove plants from the sub-experiment modules periodically without perturbing the environmental conditions of the modules.

b. Radiobiology Unit for radioisotope tracer studies.

c. Biocentrifuge for housing the onboard 1-g control specimens.

d. Clinostats capable of rotating the plants simultaneously around their cross-sectional and vertical axes.

e. Method for collecting seeds from developing plants, preserving and storing a predetermined portion of seed for return to ground, and sowing the remainder for developing a zero-g baseline strain of plants.

f. Plant housing module for developing a zero-g strain.

g. Tools and instruments (e.g., rulers) for making physical measurements (e.g., length of roots and stems).

h. Strain gauges for detecting and measuring plant movements.

i. Folded-optic photographic mirror systems for recording plant growth and development.

j. Systems for data acquisition of the bioenergetics, respiration, photosynthesis, and biorhythmic movements.

FPE-peculiar equipments described are intended for the dwarf marigold experiment. However, because of the broad spectrum of requirements for the analyses and measurements for this study, the requirements will satisfy a variety of studies involving different plant species.

For the ambient particulate-radiation study requirements, seeds will be sandwiched between two thin sheets of plastic dosimeters (a packet) containing appropriate grooves on the inner surfaces for snugly imbedding 100 seeds individually. The plastic dosimeters will be about 5 cm × 10 cm × 0.2-0.3 cm thick for the top layer and 0.5-1.0 cm thick for the bottom layer. A minimum of 20 of these seed-containing packets will be placed in appropriate locations in the sub-experiment modules, Plant Housing Unit, and elsewhere in the space vehicle where shielding is minimal.

Two sheets of plastic dosimeters, 0.1-0.2 cm thick, separated by 0.5 cm between sheets which are fixed to each other, and of appropriate dimensions to fit horizontally high over the plant specimens (seeds, germinating seeds, and developing plants) will be placed within each sub-experiment module to form a ceiling. These plastic dosimeters will identify the particulate-radiation size (Z number) and track path for correlating the particle "hits" with radiation-induced biological damage in the plant specimens.

3.4.1.1.3 Observation/Measurement Program. The experiment will include eight major areas of study on a single species of plant. In many cases the observations and analyses will be made on the same specimens; in others, additional specimens will be required so as not to compromise the experiment. The plants will be monitored at regular intervals during flight. Fresh specimens will be analyzed on-board in cases where preservation or re-entry stress would affect the scheduled observations or analyses following recovery. The major areas of study and their respective observations and measurements are described in the following paragraphs.

The biorhythm, biochemical and histochemical study will concentrate on:

a. Endogenous plant rhythms; data will be telemetered to ground for immediate evaluation.

b. Gross biochemical changes in saponifiable and nonsaponifiable lipids, free and bound proteins, and soluble and insoluble carbohydrates.

c. Morphological observations and measurements of fresh specimens, which will subsequently be quick-frozen and preserved for return to Earth for histo- and cytochemical analyses.

The intermediary metabolism and hormone interaction study will investigate the relationship of growth factors and enzymes on intermediary metabolism and growth, development and epinasty of plants. Observations and measurements will include:

a. Photographic records of growth, development and epinasty.

b. Biosynthesis and/or rate of growth factors auxin, gibberellin, cytokinin, and ethylene using radioactively tagged compounds. For example, the ethylene biosynthesis study will require exogenous application of methionine labelled with radioactive carbon, C^{14}, in the C_3 and C_4 positions.

c. Analyzing the leaves, petioles, stems and roots for activity of enzymes (e.g., peroxidase) involved in intermediary metabolism.

The plants will be preserved chemically or cryogenically as scheduled in the experimental protocol and stored for return to Earth for analyses of growth factors and enzyme activity.

The study on structure and morphogenesis will include:

a. Continuous photographic records of the sequence of gross changes during morphogenesis.

b. Histological examination of the various tissues and organs.

c. Cytological analyses of various cell types at sequential stages in morphogenesis, with special attention to detailed examination of:

 1. Cell wall structure, including cellulose orientation, interfaces between cells, and the three-dimensional shape and integration of pit fields.

 2. Structure of cell organelles.

 3. Fine-structure of the cells by electron microscopy.

 4. Certain histo- and cytochemical features of the cells.

d. Examination for pathological anatomical changes.

e. Evaluation for structural evidence of change or modification in cell, tissue, and organ polarity.

f. Examination to determine the positions of cell organelles and inclusions for evaluating the statolith and other theories of the mechanism of gravitational response.

The specimens will be fixed either chemically or cryogenically at pre-selected stages of development and stored for return to Earth for the histological, cytological and pathological studies. The study on amino acid metabolism will include:

a. Examination of the pathways by which the molecules of methionine, cysteine and their derivatives are formed.

b. Characterization of the enzymes which catalyze the transformation of the above amino acids.

c. Studies to correlate proline, its derivatives and homologs.

d. Investigation of the biosynthesis and catabolism of essential amino acids in plants subjected to forces ranging from zero to 2 g's.

e. Analyses of the amount and composition of the free amino acid pool.

The study on membranes and membrane-regulated processes will involve:

a. Investigating extracellular and intracellular calcium distribution.

b. Investigating cellular membrane function by studying solute uptake rate, osmotic potential, cell water potential, and rates of exchange of ions metabolically related to calcium.

c. Investigating the cellular level and rate of synthesis of DNA, RNA and proteins, the results of which will be correlated with nuclear structure and general growth characteristics.

The study on adaptive responses will include:

a. Examining the cell wall substance, the patterns of germination, and the development of seeds.

b. Analysis of developing seedlings for several enzymes and isoenzymes (e.g., peroxidases, aromatic amino acid deaminases, lipoxidases) of metabolic importance to cell wall biosynthesis.

c. Investigating processes of cell division, osmosis, permeability, and ionic conductivity.

d. Quantitative analytical measurements of such cell wall materials as lignin, cellulose, pectic and cuticular substances.

e. Determining the influence of temperature, pH, oxygen, light, metal ions, and hormones on seed germination and development.

f. Conducting stress physiology and measuring cell wall components in developing seedlings, and germination profile of F_2 plants.

The study on the biological effects of ambient particulate radiation will include:

a. Examining the plants for radiation-induced cytological abnormalities, chromosomal aberrations (frequency and kind), genetic and somatic mutations, gross morphological effects on growth and development, and damage to leaves, etc.

b. Recovering both the seeds flown dormant and the seeds harvested from space-grown plants and planting them and seeds from their progeny for several generations in a controlled environment to investigate radiation effects on germination frequency and rate, seedling survival, growth and development, seed production, and somatic and genetic mutations.

c. Recovering and analyzing the plastic dosimeters to identify the particle size (Z number) and track path for correlating particle "hits" with biological damage.

The study on respiration and photosynthesis will involve:

a. Continuous measurement of gas exchange data (i.e., O_2 and CO_2) which will be used for determining photosynthetic and respiratory and assimilatory and respiratory quotients with time through the course of plant development from seed to maturity.

b. Continuous measurement of light energy for interpretation of results.

3.4.1.1.4 Interface, Support & Performance Requirements. Environmental control requirements are:

a. Temperature: 297 ± 1°K (24 ± 1°C) (75 ± 2°F) for 90% of flight; within range of 277.4 to 305°K (4.4 to 32°C) (40 to 90°F) for balance of flight.

b. Atmosphere: 18-22% O_2 (pO_2 = 135 - 165 mm Hg), 78% N_2 (pN_2 = 595 mm Hg), 0.03 - 1% CO_2 (pCO_2 = 0.2 - 7.6 mm Hg), plus usual percentages of argon and other trace gases.

c. Relative humidity: 70 ± 10% for 90% of flight time.

d. Lighting: Daylight fluorescent, 1100 lum/m^2 (102 ft-C), 16 hr on and 8 hr off until fixation in Modules I-III, incl.; continuous from 5th day until fixation in Module IV; continuous in Module V; schedule TBD in Module VI; none in Module VII.

e. Atmospheric isolation: Not required, but temperature of incoming air from spacecraft must be controlled within ± 1°K.

f. Noise isolation: Required if noise level will exceed 130 dB at any time (e.g., launch or reentry).

g. Vibration isolation by shock-absorbing mountings.

h. Gravity level in orbit: 10^{-5} g or less for 95% of time. Not > 10^{-3} g during spacecraft maneuvers.

Data management requirements are:

Parameter	Units, Range	Frequency of Measurement
Temperature	297 ± 1°K (75 ±2°F)	1/30 min
Relative humidity	70 ± 10%	1/60 min
Atmos. pressure	1 Earth atmosphere ± 10%	1/180 min
pO_2	150 ± 15 mm Hg	1/180 min
pCO_2	3.9 ± 3.7 mm Hg	1/180 min
Leaf movement	90 ± 30°	1/15 min
Light	Verification	1/24 hr
Camera	Verification	1/24 hr
Water	Verification	TBD

Output signal: Type, amplitude, and resolution to be compatible with S/C system.

Readout: CORE-memory data dump once per 24 hr. acceptable.

Telemetry: Ground-station records to be furnished to PI in engineering units.

Time identification: S/C clock and timer required.

Special requirements are recovery of flight package, time-lapse photography in Module IV, fixation or freeze-drying of specimens in Modules I-III inclusive, and gas analysis in Module III.

Experiment/laboratory interface information and requirements are:

Envelope: 2 packages, each 40 cm (16 in.) dia. × 30 cm (12 in.) high.

Weight: 9 kg (20 lb) each; 18 kg (40 lb) total.

Power required: 30 W ± at 27.5 ± 2.5 v dc. each; 60 W total.

Data requirements: Storage in S/C memory; data dump once/24 hr. Data to be recorded by ground stations and transmitted ASAP to launch site for display there in engineering units. Channels required are 2-4 for temperatures, 2 for relative humidities, 5 for light verification, 1 for pCO_2, 1 for pO_2, 1 for total pressure, 1 for acceleration (at critical times), 1 for shock (at critical times), 1 for vibration (at critical times), and 5 for verifications (camera, fixation, germination).

Commands: All from onboard timer or personnel.

Thermal requirements: 25 W ± dissipation to S/C sink.

General purpose equipment: None.

Common-use equipment: Freeze-drying apparatus; gas-analysis apparatus.

Special requirements: Mounting of package with longitudinal plant axes perpendicular to thrust axis of spacecraft; noncyclical temperature variations within allowable range; no direct air impingement on experiment package or any portion thereof, or on any specimen within the package; and no contaminants within the package encasement.

Duration of experiment: Flight time 35 days, nominal; range 35-150 days.

Crew support requirements are:

Experiment setup and checkout: All types of research – 8-12 hr/setup; minimum of 1 per 35 days; 3 to 4 in 150 days.

Research Activities:

Photography – Still, 30 minutes per event; 4-5 events every 35 days; total of 150 days.

– Time lapse, once every 30 minutes; 150 days.

Visual observations – 1 hr/day; 150 days.

Removal of specimens – 1 hr/event; 3-4 events/35 days; 150 days.

Preservation (chemical or cryogenic) and storage of specimens – 1 hr/event; 3-4 events/35 days; 150 days.

Analysis of gas sample readouts – 30 min/event; 1 event/day; 150 days.

Analysis of strain gauge readouts – 10 min/event; 6 events/day of continuous recording; 150 days.

Preparation and chemical analyses of specimens – 12 hr/day; 5 days/event; 3-4 events/35 days; 150 days.

Collection of seeds – Once/event; 1 event/35 days; 3-4 events in 150 days.

Experiment Termination: 8-12 hr/event; 1 event/35 days; 3-4 events in 150 days.

Skill Level (optimum): 1 highly trained botany technician with radiobotany experience; 1 professional botanist, preferably with radiobotany experience.

Prelaunch and launch requirements are maintenance of plant experiment module integrity, including temperature, gas composition, humidity, lighting, etc.

Reentry and post-reentry requirements are the maintenance of plant experiment module integrity, including temperature, gas composition, humidity, etc., and return to ground study laboratory within 12 hours of recovery.

The experiment is in the early conceptual and breadboard stage. Estimated development time to flight readiness is four years.

3.4.1.1.5 Potential Role of Man. The degree to which a flight crew or an onboard investigator would interphase with the experiment is quite flexible and can be varied according to available crew time. However, it is highly desirable to have man's participation so that the experiment can be accomplished considerably more effectively and with significantly less developmental cost and time for flight experiment hardware. The minimum effort required of onboard personnel would involve general types of activity such as transferring research specimens in modules or bulk transport container from logistic carrier into Plant Housing Unit and installing in the biocentrifuge mount; coupling all appropriate connections between the specimen modules, the

zero-g centrifuge mount, the Plant Housing Unit and the CORE; completing checkout of all the systems; placing the plastic dosimeter packets containing seeds in appropriate places; placing dosimeter sheets in appropriate places within the sub-experiment modules; initiating specific experiment cycles (e.g., germination of seeds, day-night lighting cycle) once the desired level of hypogravity has been attained; activating the controls of various systems (e.g., ECS, data management and recording units, time-lapse photography); removing plant specimens from the sub-experiment modules, taking still photographs of the roots, stems, flowers, leaves and of unusual events, and fixing (chemically or cryogenically) for preservation and storage for return to Earth for analyses; observing and documenting unusual events; repairing and maintaining equipment; and terminating and transferring the experiment package to the logistic carrier for return to Earth. A maximum effort would include the above as well as conducting onboard biochemical, physiological, morphological, and other measurements and analyses. Obviously the latter effort would be very time-consuming. Hence, rather than having all the measurements and analyses done onboard, it would be prudent to limit such activities to those requiring real-time observations, measurements and/or analyses of fresh plant specimens. The latter would be mandatory in situations where preservation or reentry stress alters the scheduled observations or analyses following recovery.

3.4.1.1.6 Available Background Data. The sole source is a flight proposal, with the same title, provided by NASA, ARC.

3.4.1.2 Plant Growth at Low-g Level. This experiment is to determine the morphological and cytological end points of development of a higher plant under hypogravity.

3.4.1.3 Orbital Growth of Dicotyledonous Seedlings. The objective of this experiment is to study the effect of weightlessness on pea seed germination and seedling development, and compare patterns of auxin origin, transport and action in pea seedlings to those seen in wheat seedlings.

3.4.1.4 Biochemical and Biorhythmic Changes in Plants Due to Reduced Gravity. The objective of this experiment is to determine whether the geotropic, biochemical, and biorhythmic criteria of normal plant behavior would have a new baseline in the absence of earth gravity.

3.4.1.5 Effects of Weightlessness on Gametogenesis and Morphogenesis in Gametophytes. The objective of this experiment is to test the hypothesis that hypogravity will induce multicellular differentiation and restricted sexuality, since pteris gametophytes are positive to gravity along their dorsiventral alignment.

3.4.2 GRAVICEPTION AND TROPISM. The objective of this experiment class is to determine the mechanism and thresholds for graviception and tropism of plants by studying the responses (e.g., orientation, morphology, cellular physiology, and biochemistry) of plant growth in the space environment and to fractional gravity

(acceleration) forces in space. Based on previous flight and clinostat experiences, significant findings are anticipated. An experiment requirements summary is shown in Table 3-7.

3.4.2.1 Physiological Responses of Plants to a Hypogravity-Gradient Environment

3.4.2.1.1 Scientific Objectives. The objectives of this study on the wheat and/or pepper plant are:

a. To investigate the responses of plant growth to hypogravity-gradient forces in space, as compared with responses of plants grown on gravity-gradient clinostats.

b. To determine whether the clinostat gives a valid indication of the effect of hypogravity in space.

c. To test the hypothesis that hypogravity thresholds exist for the onset of epinasty in plants.

3.4.2.1.2 Description. The experiment design consists of growing plants on an onboard biocentrifuge. By placing the plants at varying distances from the center of rotation along the radial arm of the centrifuge, centrifugal forces of different intensities will be induced by rotating the centrifuge at a predetermined rate. For reasons of stability it would be desirable to have two centrifuges rotating simultaneously at the same speed but in opposite directions. Control experiments will be conducted with plants cultured in a similar fashion and maintained (a) in space but off the biocentrifuge (zero-g control), (b) on horizontal clinostats on the ground, and (c) normal to Earth's gravity.

Growth, orientation, cellular physiology, and biochemical activities will be used to score the effects. Photographic records of the plant organs will be used for precise measurements of organ orientation to quantify the latter with varying gravitational forces. The same plants will be quick-frozen and stored for return to Earth for analyses. Biochemical analyses will be carried out to identify and to quantify the reactions that control epinasty.

Optimum flight in orbit is three days; maximum is seven days.

The facilities and/or capabilities provided by the CORE will be used for this experiment as follows:

a. Taking time-lapse photography of growth and development.

b. Taking still photographs of the orientation (epinasty) of the leaves, stems, roots, etc.

c. Recording observations visually and/or verbally.

Table 3-7. Experiment Requirements Summary (Class: Graviception and Tropism)

EXPERIMENT NO. AND TITLE	3421 Physiological Response of Plants to a Hypogravity-Gradient Environment		3422 Growth Transients in Roots Exposed to a Weightless Environment												NOTES
SPECIMEN	Wheat or pepper Triticum Vulgare or Capsicum Annum		Corn Seedlings												
LOCATION	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	
NO. OF SPECIMENS															
HOLDING CAGES															[1] No periodic cues at whole-number fractions of 24 hours.
Standard	8 pots	64 pots													
Metabolic															
Colony															
MAN REQUIREMENTS, hr															[2] Normal Laboratory Max.: $\begin{cases} 10^{-3}\text{g } 90\% \text{ of time} \\ 10^{-2}\text{g } 10\% \text{ of time} \end{cases}$
Skill 1															
Setup	8	16													
Daily Average [3]	0.1	0.2													
Terminate	8	16													
Skill 3															[3] Ad Hoc observations required up to 8 hr/day. They cannot be scheduled and are part of the daily average. Crew time is average.
Setup															
Daily Average [3]															
Terminate															
Skill 4															[4] SMAC = Space maximum allowable concentration for man.
Setup															
Daily Average [3]															
Terminate															
EXPERIMENT DURATION, days	3-7	3-7	2	2											[5] No offensive or noxious odor.
ENVIRONMENTAL REQMTS															[6] TBD; minimal to reasonable engineering design effort.
pO_2, mm Hg	150±10	150±10	150±10	150±10											
Total Pressure, mm Hg	760±10	760±10	760±10	760±10											
pCO_2, mm Hg	1-3	1-3													[7] Arterial & Venous
pCO, mm Hg															
pNH_3, mm Hg															[8] Includes blood, feces, urine, bacterial, gas, and biopsy samples.
pH_2O, mm Hg	9-11	9-11													
Temperature, °K (°C)	(20±2) 293±2	(20±2) 293±2	27.5±2.5) 300.5±2.5	27.5±2.5) 300.5±2.5											[9] Samples per week/ tests per sample
O_2 Consumption, kg day	Negl	Negl	Negl	Negl											
CO_2, kg day	Negl	Negl	Negl	Negl											
Noise, dB	[6]	[6]	[6]	[6]											
Vibration, g (Hz)	[6]														[10] Measurements made at holding unit level only; () = each organism.
Acceleration, g	[11]	.06 .12 .18...1.0	[11]	1.0											
Radiation, C/kg	[6]	[6]	[6]	[6]											
Illumination, lum/m^2 (ft-c)	(90±10) 970±100	(90±10) 970±100	(90±10) 970±100	(90±10) 970±100											[11] Max acceleration 10^{-5} 90% of time; 10^{-3} 10% of time.
Trace Contaminants															
NUMBER AND FREQUENCY OF MEASUREMENTS															

Table 3-7. Experiment Requirements Summary (Class: Graviceptionand Tropism), Contd

EXPERIMENT NO.	3421		3422												NOTES
LOCATION	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	
NUMBER AND FREQUENCY OF MEASUREMENTS															
Number and Frequency of Measurement															
pO_2, hourly		X													
pCO_2, hourly [10]		X													
pNH_3, hourly [10]															
pH_2O, hourly [10]		X	X 4X/hr	X 4X/hr											
Temp., hourly [10]		X	X 4X/hr	4X/hr											
Noise, continuous [10]		X													
Vibration, cont. [10]		X													
Acceleration, cont. [10]		X													
Radiation, cont. [10]		X													
Organism Sacrifice/wk															
Urine Analysis/wk															
Organism Visual Monitorings/wk															
Organism Recovery Preparation, No.															
Organism Live Recovery, No.															
Illumination, No./meas.															
Radiobiologies/wk															
Total Pressure		X	X 4X/hr	X 4X/hr											
Event Verification		X	X	X											
Illumination		X	X	X											
Leaf Movement		X													
Biochemistries															
Specimen Fixation															
Centrifuge rate		X													
POWER															OTHER
AC															
Continuous, watts															
Peak, watts															
Peak Duration, min/day															
DC															
Continuous, watts		320	30	60											
Peak, watts															
Peak Duration, min/day															
WEIGHT															
Organisms and Cages, kg (lb)		20 (44)	1.35 (3)	2.7 (6)											
Ancillary Research Equipment, kg (lb)		5 (11)	0.2 (0.44)	0.2 (0.44)											
VOLUME															
Organisms and Cages, m^3 (ft^3)		0.2 (7.0)	0.1 (3.5)	0.2 (7.0)											
Ancillary Research Equipment, m^3 (ft^3)		0.01 (0.35)	0.01 (0.35)	0.01 (0.35)											
LOGISTICS															
Weight at Launch, kg (lb)		25 (55)	1.55 (3.4)	2.9 (6.3)											
Supplies/Mo. Up, kg (lb)															
Supplies/Mo. Down, kg (lb)															
Weight at Termination, kg (lb)		25 (55)	1.5 (3.3)	2.9 (6.3)											
Volume at Launch, m^3 (ft^3)		0.21 (7.4)	0.11 (3.9)	0.21 (7.4)											
Supplies/Mo. Up, m^3 (ft^3)															
Supplies/Mo. Down, m^3 (ft^3)															
Volume at Termination															
Frozen Specimens Down															
Live Organisms Up		X	X	X											
Live Organisms Down															
Frozen Specimens Up															
Other Film			X	X											
COMMUNICATIONS															
Voice, hr/day		TBD													
TV, B&W, hr/day		X	X	X											
TV, Color, Ad Hoc		X	X	X											

d. Coupling the plant experiment module in the biocentrifuge and the Plant Housing Unit to the CORE Data Management Unit and the Life Science Support Unit for:

 1. Research programming command purposes (e.g., ECS cycling).

 2. Management of environmental data readout such as temperature, humidity, gas composition (including buildup of toxic contaminants such as ethylene), g-environment, rotational velocity of biocentrifuge, etc.

 3. Data acquisition of the bioenergetics, respiration, lighting and light intensity, etc.

e. Preserving the plant specimens cryogenically and storing for return to Earth for analyses.

f. Checking out, adjusting, repairing and/or modifying the experiment module.

Additional facility/equipment requirements are:

a. Capability for onboard personnel to remove plants from the experiment module periodically without perturbing the environmental conditions of the module.

b. Biocentrifuge for housing and growing the experimental specimens.

c. Clinostats for growing the zero-g control specimens in the Plant Housing Unit.

3.4.2.1.3 Observation/Measurement Program. The following observations and/or measurements will be recorded during orbit:

a. Continuous time-lapse photography of growth and development.

b. Still photographs of the plant parts – leaves, stems, roots, etc.

c. Temperature, humidity, lighting and light intensity, rotational velocity of biocentrifuge, gas composition, vibration, etc.

3.4.2.1.4 Interface, Support & Performance Requirements. Environmental control requirements are:

a. Temperature: Prelaunch: 293 ± 3°K (68 ± 5°F)
 Orbit: 293 ± 3°K (68 ± 5°F)
 Recovery: 113 ± 20°K (-256 ± 36°F).

b. Atmosphere: Sea level air composition and pressure.

c. Relative humidity: 55 ± 5%.

d. Lighting: Sufficient intensity for photography.

e. Atmospheric isolation: Not required, since spacecraft air composition meets experiment requirements, but cooling will be required if spacecraft air temperature exceeds 295°K (72°F).

f. Noise isolation: Requirement TBD.

g. Vibration isolation: By shock-absorbing mounting.

h. Gravity level during orbit: 0-g controls < 10^{-4}g.

Data management requirements are:

a. By telemetry: Temperature, relative humidity, centrifuge rotation rate; (pressure from spacecraft data).

b. Frequency of transmission: Requirement TBD.

c. By recovery: Photographic films.

Special requirements include the centrifuge and zero-g controls. If other than man-rated Biocentrifuge, arms must be about 3 m in diameter (1.5 m. radius) to impart from 1/6 g to 1 g force in increments of 1/6 g at one time and must be able to carry a minimum of 36 plants and containers (a minimum of 6 at a given g-level). Cameras, lights, and controls will be mounted separately. Six cameras are to be actuated sequentially to photograph each plant every 10-15 minutes for 3 to 7 days.

Zero-g controls must be kept in dark continuously during flight.

Experiment/laboratory interface requirements are:

a. Envelope: If other than man-rated Biocentrifuge, centrifuge about 3 m (10 ft) diameter × 0.65 m (2 ft) thickness (height).

b. Weight: About 90 kg (200 lb) centrifuge plus plants, containers, cameras, and controls.

c. Power required: 500 watts continuous (to drive centrifuge, power equipment, cameras, etc.).

d. Data requirements: 5 channels.

e. Command requirements: None (all operations to be crew-initiated).

f. Thermal: 1500 watts dissipation.

g. General purpose equipment requirement: None.

h. Common use equipment requirements: Freezer, cameras (both still and time-lapse), centrifuge, data management and recording unit, ECS system, etc. of CORE.

i. Duration of flight: 3 days optimal; 7 days maximum.

Crew support is required for experiment setup, coupling to CORE (all applicable systems) and check out (8-12 hr) and for the following research activities:

a. Photography: Time-lapse once every 10-15 min for duration of experiment (3 to 7 days); still (see Experiment Termination); load camera; remove film for recovery.

b. Visual observations: Via TV or ad hoc, 3 min/observation, 3/day.

c. Centrifuge: start and stop; control rotation rate.

d. Activate Data Management Unit and ECS system, and analyze data readout once per day for duration of experiment (3 to 7 days).

e. Lighting: Control sequence for photography.

f. Experiment Termination: 8-12 hr to remove specimens from centrifuge and Plant Housing Unit (zero-g controls), take still photographs of various parts (e.g., leaves, stems, roots) of each plant, and freeze and preserve specimens for return to Earth.

Crew skill level required is one botany technician with training in photography or a member of the crew with minimal training in botany and photography.

Prelaunch and launch requirements at launch site are: Plant laboratory with analytical balance, hot plate, vacuum oven and pump, photographic equipment for ground controls, horizontal clinostats, incubators, liquid nitrogen refrigerators, etc.

Reentry and post-reentry requirements are the maintenance of frozen specimens at cryogenic temperature; transfer to laboratory within 12 hours post-recovery.

Estimated development time is three years from initiation to flight readiness.

3.4.2.1.5 Potential Role of Man. Man's participation is highly desirable to accomplish the experiment most effectively and with significantly less developmental time and cost of flight-experiment hardware. Man would transfer the specimens from the logistic carrier into the Plant Housing Unit for 0-g clinostat control and would mount the variable-g experimental specimens on the centrifuge, set up the experiment, couple the applicable systems to the CORE, check out all systems, monitor the data management and recording units, analyze the readout data, control the lights sequentially for time-lapse photography, monitor the experiment to insure its success, remove the specimens at termination of experiment, take still photographs of various parts of specimens (e.g., leaves, stems, roots), quick freeze and store for return to Earth.

3.4.2.1.6 Available Background Data. The sole source is a flight proposal, by the same title, provided by NASA, ARC.

3.4.2.2 Growth Transients in Roots Exposed to a Weightless Environment. The purpose of this experiment is to test the hypothesis that roots will display changes in the distribution of relative elemental growth rates when subjected to low gravity environments.

3.4.3 EFFECT OF THE SPACE ENVIRONMENT ON PLANT GENETICS. The objective of this experiment class is to investigate modifications in the genetics of plants exposed to the space environment and elucidate the mechanisms underlying these changes. Based on previous flight experiences, a significant increase in aberrations and mutations is anticipated, especially in long-term flights. An experiment requirements summary is shown in Table 3-8.

3.4.3.1 Low-g Effects on Tradescantia

3.4.3.1.1 Experiment Scientific Objective: The objectives of this study on the spider wort (Tradescantia) are:

a. Mainly to confirm, determine causes of, and quantify space flight effects on somatic and meiotic cell spindles.

b. To determine genetic and biological effects of ambient high-Z particle radiations.

c. To examine further the biocompatibility of a higher plant population in a small, sealed, illuminated chamber in weightlessness.

d. To test the effect of cell and nuclear or chromosome volume on sensitivity to low-g effects.

e. To study synergistic effects of onboard controlled radiation and space flight factors on spindle malfunction.

f. To look for adverse effects on cell division.

3.4.3.1.2 Description. The proposed flight experiment is a comprehensive program designed to verify and extend the findings from the Biosatellite II mission, ascertain long-range flight effects, and elucidate the mechanisms responsible for the effects observed. It is designed for accommodation in available orbital flight opportunities and will be comprised of appropriate ground controls and the following three flight experimental payloads: (a) one for studying the 0-g effect, (b) one for studying the synergistic effect of 0-g and controlled ionizing radiation, and (c) one for a 1-g flight control. While it will be economically prudent to orbit all three payloads simultaneously, they can be flown individually or in combination as follows without compromising the experiment: (a) the 0-g study payload alone, (b) the 0-g and 1-g control payloads simultaneously (this would definitely be preferable to flying the 0-g study specimens alone), or (c) the 0-g and radiation payloads simultaneously.

The 0-g study payload can be flown in a spacecraft with limited research facilities/capabilities, the 1-g control payload will require an onboard centrifuge for rotating

Table 3-8. Experiment Requirement Summary (Class: Effect of the Space Environment on Plant Genetics)

EXPERIMENT NO. AND TITLE	3431 Low-g Effects on Tradescantia		3432 Effects of UV Irradiation on Mitotic Recombination in Weightlessness [12]												NOTES
SPECIMEN	Spider Wort Tradescantia		Green Flagellated Alga												
LOCATION	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	
NO. OF SPECIMENS	2	1													
HOLDING CAGES Standard Metabolic Colony	2	1	Special Quartz Containers	Special Quartz Containers											[1] No periodic cues at whole-number fractions of 24 hours.
MAN REQUIREMENTS, hr Skill 1 Setup Daily Average [3] Terminate															[2] Normal Laboratory Max.: $\begin{cases} 10^{-3}g\ 90\%\ \text{of time} \\ 10^{-2}g\ 10\%\ \text{of time} \end{cases}$
Skill 3 Setup Daily Average [3] Terminate	2 12	4 24													[3] Ad Hoc observations required up to 8 hr/day. They cannot be scheduled and are part of the daily average. Crew time is average.
Skill 4 Setup Daily Average [3] Terminate															[4] SMAC = Space maximum allowable concentration for man.
EXPERIMENT DURATION, days	5-30	5-30													[5] No offensive or noxious odor.
ENVIRONMENTAL REQMTS pO_2, mm Hg pN_2 or Total Pressure, mm Hg pCO_2, mm Hg	150±10 760±10	150±10 760±10													[6] TBD; minimal to reasonable engineering design effort.
pCO, mm Hg pNH_3, mm Hg pH_2O, mm Hg Temperature, °K (°C)	12-15 (19±2) 292±2	12-15 (19±2) 292±2	(27±1.5) 300±1.5	(27±1.5) 300±1.5											[7] Arterial & Venous
O_2 Consumption, kg day CO_2, kg day Noise, dB Vibration, g (Hz)	Negl Negl [6] [6]	Negl Negl [6] [6]	0 0	0 0											[8] Includes blood, feces, urine, bacterial, gas, and biopsy samples.
Acceleration, g Radiation, C/kg Illumination, lum/m^2 (ft-c) Trace Contaminants	[7] [6] 5400 (500) [4]	1 5400 (500)													[9] Samples per week/ tests per sample
NUMBER AND FREQUENCY OF MEASUREMENTS															[10] Measurements made at holding unit level only; () = each organism.
															[11] Acceleration (Max.), 10^{-5} 90% of time; 10^{-3} 10% of time.
															[12] Video microscopy required.

Table 3-8. Experiment Requirement Summary (Class: Effect of the Space Environment on Plant Genetics), Contd

EXPERIMENT NO.	3431		3432												NOTES
LOCATION	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	
NUMBER AND FREQUENCY OF MEASUREMENTS															
Number and Frequency of Measurement															
pO_2, hourly	X	X													
pCO_2, hourly [10]															
pNH_3, hourly [10]															
pH_2O, hourly [10]	X	X													
Temp., hourly [10]	X	X	X	X											
Noise, continuous [10]	X	X													
Vibration, cont. [10]	X	X													
Acceleration, cont. [10]	X	X	X	X											
Radiation, cont. [10]			X	X											
Organism Sacrifice/wk															
Urine Analysis/wk															
Organism Visual Monitorings/wk															
Organism Recovery Preparation, No.															
Organism Live Recovery, No.															
Illumination, No./meas.															
Radiobiologies/wk															
Total Pressure	X	X	X	X											
High-Z Particle Radiation															
UV Radiation			X	X											
Event Verification	X	X	X	X											
Centrifuge rate			X	X											
POWER															OTHER
AC															
Continuous, watts															
Peak, watts															
Peak Duration, min/day															
DC															
Continuous, watts	50	100	5	10											
Peak, watts			25	50											
Peak Duration, min/day			0.1	0.1											
WEIGHT															
Organisms and Cages, kg (lb)	4 (8.8)	8 (1.76)	9 (20)	18 (40)											
Ancillary Research Equipment, kg (lb)	1 (2.2)	1 (2.2)	0.5 (1)	0.5 (1)											
VOLUME															
Organisms and Cages, m^3 (ft^3)	0.04 (1.4)	0.08 (2.8)	0.05 (1.8)	0.10 (3.5)											
Ancillary Research Equipment, m^3 (ft^3)	0.01 (0.35)	0.01 (0.35)	0.01 (0.35)	0.01 (0.35)											
LOGISTICS															
Weight at Launch, kg (lb)	5 (11)	9 (19.8)	9.5 (20.9)	18.5 (40.7)											
Supplies/Mo. Up, kg (lb)															
Supplies/Mo. Down, kg (lb)															
Weight at Termination, kg (lb)	5 (11)	9 (19.8)	9 (20.9)	18 (40.7)											
Volume at Launch, m^3 (ft^3)	0.05 (1.8)	0.09 (3.2)	0.06 (2.1)	0.11 (3.9)											
Supplies/Mo. Up, m^3 (ft^3)															
Supplies/Mo. Down, m^3 (ft^3)															
Volume at Termination															
Frozen Specimens Down															
Live Organisms Up	X	X	X	X											
Live Organisms Down	X	X	X	X											
Frozen Specimens Up															
Other															
COMMUNICATIONS															
Voice, hr/day	TBD	TBD	TBD	TBD											
TV, B&W, hr/day	X	X	X	X											
TV, Color, Ad Hoc	X	X	X	X											

the specimens at 1 g, and the 0-g radiation-synergism study payload will require a controllable onboard radiation source and exposure facility (or a prepackaged payload with a built-in radiation source, that can be turned on and off by onboard personnel). The arrangement of the specimens for the 0-g radiation study must be such as to permit exposure of each of three or four groups of plants to different prescheduled radiation-dose levels to obtain a dose-response series.

The present concept of the hardware emphasizes the interchangeability of individual plant modules within package components and the interchangeability of the component itself. It is anticipated that much baseline data would be obtained from the use of prototype and spare-part assemblies.

The basic payload package would be cylindrical and consist of a central light source surrounded by plant modules (see Figure 3-6). Each module would contain three to five rooted cuttings making up a population of 30 to 40 plants in each of two concentric columns. An outer cylindrical shell (metal or plastic) would give structural support to the package. In the event a common-use radiation source/exposure facility is not available, one of the packages will carry a built-in radiation source. The outer shell for this particular package would be made of shielding material, the density and thickness of which would vary with the radiation source used (which remains to be decided). The shell of the nonradiation packages would be made of lightweight material. The cap would house the radiation source and its assemblies in the case of the radiation package, and high-Z particle detectors (emulsion and/or plastic dosimeters) in the others. The base of each package would house the required light ballasts, transformers, etc., and a small fan to dissipate heat from the light.

The experiment can be carried out with minimal research facility/capability requirements. As such it can be accomplished without the CORE. However, the following functions of the CORE must be provided:

a. Research programming command purposes (ECS cycling, etc.).

b. Management of environmental data readout and acquisition such as temperature, humidity, pressure, gas composition (including buildup of toxic contaminants, e.g., ethylene), g-environment, rotational velocity of centrifuge, etc., from the experiment modules.

c. Preservation and storage of specimens for recovery.

d. Check out, adjust, repair and/or modify the experiment module as may be required.

Additional facility/equipment requirements are:

a. Plant Housing Unit or module for growing the specimens in a 0-g environment under environment under specified environmental conditions.

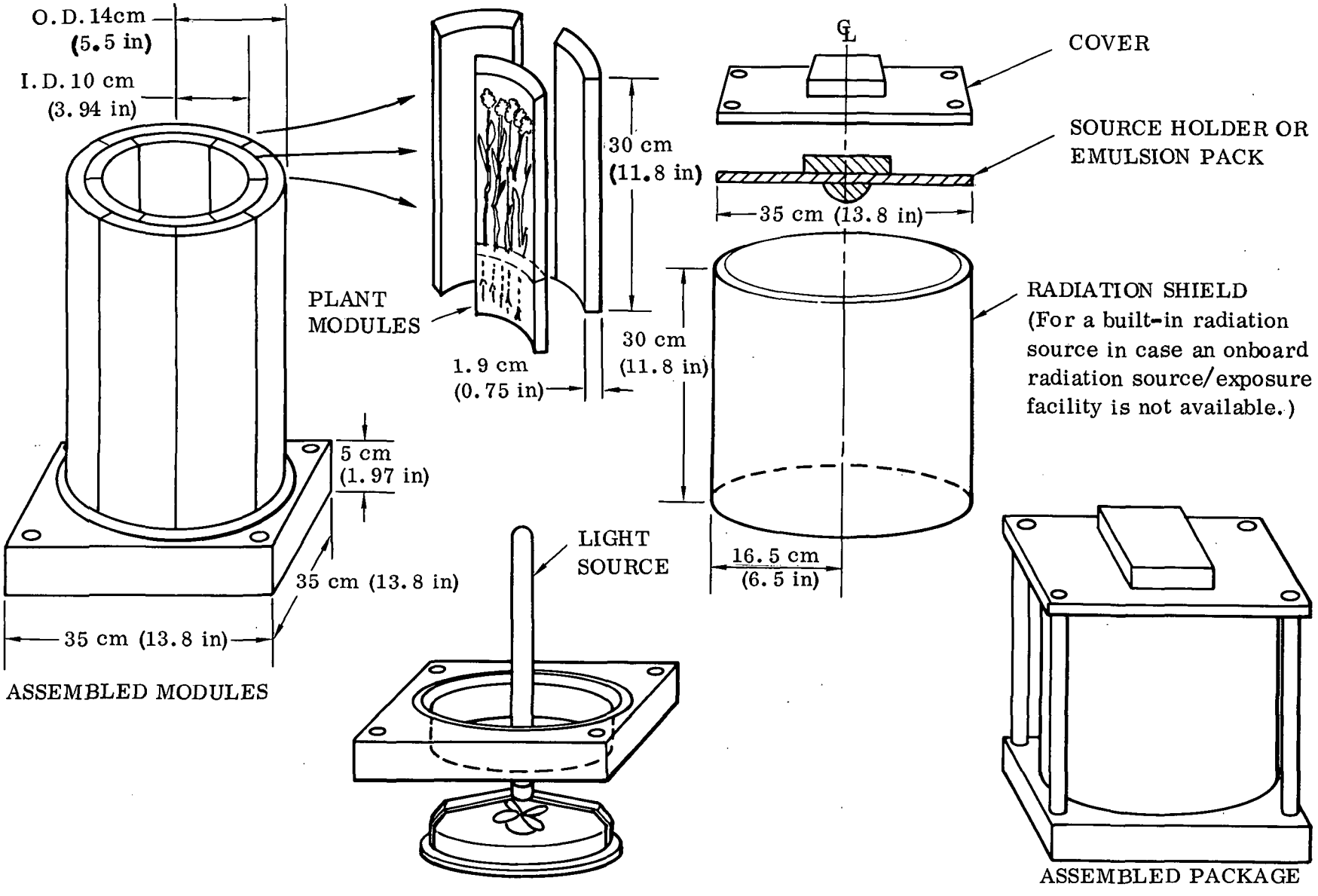


Figure 3-6. Conceptual Design of Tradescantia Flight Hardware

b. Capability for onboard personnel to remove plants from the experiment module periodically without perturbing the environmental conditions of the module.

c. Centrifuge for housing and growing the experimental specimens at 1 g (need not be man-rated).

d. Radiation source/facility (e.g., Radiobiology Unit), including specimen-mounting hardware, for exposing the specimens to graded doses of ionizing radiation.

e. Active and passive ionizing radiation dosimeters and readout capabilities.

3.4.3.1.3 Observation/Measurement Program. The following observations and/or measurements will be recorded during orbit:

a. Continuous or periodic recording of environmental factors such as temperature, humidity, pressure, gas composition, light intensity, rotational velocity of centrifuge, g-environment, etc., in the experiment modules.

b. Ionizing radiation exposure dose rate and dose delivered to the respective groups of specimens.

c. Gas analysis including buildup of toxic contaminants such as ethylene in the experiment modules.

3.4.3.1.4 Interface, Support and Performance Requirements. Environmental control requirements are:

a. Temperature: May range from 289 to 294°K (60 to 70°F).

b. Atmosphere: Normal sea level composition and pressure.

c. Relative humidity: May range from 70 to 90%.

d. Lighting inside experiment modules: 5500 lum/m^2 (510 ft-C) optimum; 1100 to 11000 lum/m^2 (102 to 1020 ft-C) tolerable.

e. Atmospheric isolation: Specimens will be in a closed system; the specified environmental conditions must be maintained, including removal of toxic contaminants (e.g., ethylene) to eliminate buildup.

f. Noise isolation: TBD

g. Vibration isolation by shock-absorbing mountings.

h. Gravity level in orbit for 0-g specimens: $< 10^{-4}$ g.

Data management requirements are:

a. Record and store temperature at 12-24 points, once/orbit, and relative humidity at 3-6 points, once/orbit.

b. Record vibration at 3-6 points continuously, acceleration (requirement TBD), and acoustic noise (requirement TBD).

c. Transmit temperature and humidity data once per orbit.

Special requirements are: Exposure to ambient high-Z radiation particles; onboard 1-g experiment centrifuge; onboard ionizing radiation source/exposure facility with appropriate shielding to meet personnel safety requirements, and hardware for mounting the specimens for exposure; and recovery of entire experiment, including preserved specimens.

Experiment/laboratory interface, information and requirements are:

a. Envelope: 0.004 m^3 (1.5 ft^3) maximum per package (payload); minimum of 3 packages.

b. Weight: Nonirradiation package 2.5-5 kg (about 5-10 lb.); irradiation package TBD.

c. Power: 50 W continuously.

d. Data transmission: 15 to 30 eight-bit words transmitted per orbit. Memory capacity of 45 to 90 words to provide for transmission loss during two consecutive orbits.

e. Command: None from ground.

f. Thermal: About 50 W dissipation to S/C sink.

g. General-purpose equipment: None required.

h. Common-use equipment: 1-g experiment centrifuge and radiation source/exposure facility.

i. Special requirement: Radiation shield for one package in case an onboard radiation source/exposure facility is not available; dosimeters (emulsion and/or plastic) for monitoring high-Z particles.

Duration of flight is 5 to 30 days.

Crew support is required for experiment setup, coupling of applicable systems to CORE, and checkout of all systems (8 hr), and the following research activities:

a. Activate Data Management Unit and ECS system, analyze data readout at least once or twice per orbit for duration of experiment, and transmit data once per orbit (30 minutes per event).

b. Exercise judgment as to suitable times and procedures for chemical fixation; either actuate semi-automatic fixation device or (preferred) remove specimens from modules and fix (2-3 hr/event, 4 events during flight of 5 to 30 days).

c. Centrifuge: Start and stop; periodically monitor acceleration readout data (2-3 min/event, 3-4 events/24 hr).

d. Radiation: Start and stop; periodically monitor radiation dose readout (2-3 min/event, 3-4 events/24 hr).

e. General monitoring of experiment: 30 min/event, 3-4 events/24 hr.

f. Adjustment, repair, etc., of equipment as necessary: Time requirement depends upon nature of service to be done.

g. Experiment termination: Remove experimental packages from Plant Housing Unit (0-g study), centrifuge (1-g control), and radiation exposure facility; prepare for return to Earth – 6-8 hr.

Skill level is minimal, 2 to 3 hours of training before launch.

There are no constraints on orbital altitude and inclination.

Prelaunch and launch requirements are for the flight hardware to be held in bonded locker prior to loading for launch. Prelaunch hardware inspection, cleaning, and checkout to be performed. Engineering assistance is required to checkout electrical and telemetry sensing systems within the package and the package-spacecraft interface. Launch site facilities are to provide clean modern laboratories with usual provisions of distilled water, tap water, gas, filtered air, air conditioning, and electricity, and equipment. A controlled plant-environment chamber is required for maintenance of plants before launch.

All fixed specimens and intact packages must be recovered. Environmental conditions, vibration, shock, acceleration, etc., must be held within specified limits throughout the entire recovery period. The packages must be delivered to the recovery laboratory, at which point the experimenters will assume responsibility for post-flight fixation and return to home laboratory. The latter activity will require a controlled environment during transit.

Estimated development time is four years from initiation to flight readiness.

3.4.3.1.5 Potential Role of Man. Although the experiment can be fully automated, man's participation is highly desired for its successful accomplishment at significantly less developmental time and cost of flight hardware. The presence of man to verify certain functions and to manually perform these functions in case of an equipment failure would be valuable. His minimum research activities would be to set up the experiments, couple the packages to the Data Management Unit, Life Sciences Experiment Support Unit, etc., check out all systems, initiate the experiments, take automated data readout and transmit to Earth as required, fix appropriate specimens periodically as specified, monitor the experiments periodically and adjust, repair and/or modify the experiment/facilities as required to insure success of the experiment, terminate the experiment, and prepare packages and fixed specimens for return to Earth.

3.4.3.1.6 Available Background Data. The sole source is a flight proposal, by the same title, provided by NASA, ARC.

3.4.3.2 Effects of UV Irradiation on Mitotic Recombination in Weightlessness. The objective of this experiment is to test the hypothesis that under hypogravity and UV irradiation, cell yield will be greater, frequency of mitotic non-disjunctions will be greater, and frequency of recombinants due to mitotic crossing over will be increased.

3.5 FPE INTERFACE, SUPPORT AND PERFORMANCE REQUIREMENTS

The summary data presented in Table 3-8 represents, in the best judgment of NASA scientists, the overall facility and experiment requirements to accomplish a realistic experimental program, and is based on some projection of the state of the art. The rationale for selection of the summary parameters is in some instances arbitrary but has as a basis the total NASA experience and knowledge gained from prior flight and experiment definition and integration programs. The basis for each data entry is given in the notes.

3.6 POTENTIAL MODE OF OPERATION

The recommended mode of operation is within a general bioresearch laboratory facility. A bioresearch centrifuge is required, attached to the general laboratory, to provide artificial-G for biology specimens. Man will work at biological investigation and laboratory maintenance 8-24 hours per day. Preferred operation is manned continuous; however, by experiment selection, periods of unmanned operation or dormancy are possible.

Biological research is highly flexible in terms of procedures, specimens, and analytical location. Given a mission profile for a defined general laboratory, NASA scientists working with the PIs can frequently restate the hypothesis and develop a new protocol within that profile and still obtain valid data. However, the basic variables -- gravity, radiation, and the absence of periodic cues -- must be met by the laboratory-provided environment. If the gravity requirements (10^{-5} 95% of the time and 10^{-4} 10% of the time) cannot be met by the support vehicle and laboratory, then a soft mounting system for the holding units must be developed. If the soft mounting system cannot provide the gravity requirements, a flyaway module may be considered; however, the docking environment and the impact of inaccessibility must be evaluated.

With regard to the specific Mode A, limited on-orbit stay time as with Space Shuttle, there are some experiments of less than 30 days duration which can be accommodated, but there are other experiments which require more than 30 days and cannot be accommodated. As for Mode B, extended on-orbit stay time, unmanned, with periodic revisits by Space Shuttle, there are some experiments which can be automated for accommodation by this mode, but the interval between crew visits should not exceed 30 days and a shorter interval such as 15 days is much preferred. Some experiments require Mode C, extended on-orbit stay time with Space Station, and this is the preferred mode for all experiments of this FPE.

3.7 ROLE OF MAN

Based on all activities in all experiments, man may potentially carry out the functions itemized below. In a high-load day in which contingencies call for the absolute maximum effort, the scientist may be required to devote 14 or more hours to experiment

Table 3-8. Plant Research Facility FPE Summary Data

Weight, kg (lb)	2232 (4920)		Note 1
Volume, m^3 (ft^3)	16 (565)		Note 1
Power, watts	3415		Note 2
Crew Skills		1	Biological Technician
		3	Biochemist
		12	Electromechanical Technician
		22	Chemical Technician
Data Rate, bps	740		Note 2
Analog Data: hours/day	3		
frequency, MHz	4		
Logistics Up, 30-day average, kg (lb)	67 (148)		Note 3
Logistics Down 3-day average, kg (lb)			
1st 2 years	50 (110)		Note 4
3rd year on	60 (132)		Note 5
Pointing and Stabilization	NA		
Orbit Altitude & Inclination	NA		

Unique Environment Requirements: Isolation from rhythmic phenomena, noise, vibration, and possibly from EMI and ESI. Acceleration allowable at holding unit $<10^{-5}g$

NOTES:
1. CORE units + FPE units + two logistic cycles of expendables + 1 complement of test subjects. Radiobiology unit and bioresearch centrifuge not included.
2. 40% of CORE units total + 75% of FPE units total = normal load.
3. 1% of FPE units + 80% of expendables to support total specimen holding capability + 16 2/3% specimen complement (equivalent to 50% replacement of specimens every 90 days).
4. 75% of logistics up.
5. 90% of logistics up.

manipulations. These occasions will be infrequent, occurring mainly at experiment setup and termination times. In contrast with a fixed load on a minimum-effort day, considering only housekeeping and colony management, the scientist may be committed to as little as two hours' time, leaving him free for creative activities such as onboard data reduction and interpretation and planning of new and follow-on experiments. The average day, including housekeeping plus ad hoc research activities, will be six to eight hours long.

a. Routine tasks (all experiments):

 1. Laboratory housekeeping, maintenance and repair.
 2. Experiment setup.
 3. Monitor organisms, hardware and data.
 4. Experiment termination.
 5. Specimen preparation for logistics return; package experiments, samples, photographs and other records for return to earth.

b. Experiment-peculiar research activities (desirable to enhance scientific value and responsiveness of experiment, but not critical to successful execution of basic experiment):

 1. Set up follow-on experiments with tissue from prior experiments, onboard organisms, and/or newly arrived organisms.
 2. Common lab techniques, e.g., mass measurement, fluid handling.
 3. Perform laboratory analysis (biochemistries).
 4. Gross morphological examination.
 5. Cytological and histological preparations and preliminary analysis.
 6. Programmed and ad hoc photography at request of P.I.
 7. Ad hoc TV monitoring in conference with P.I.
 8. Install and operate plate physiological and metabolic instrumentation, etc.
 9. Radiobiology techniques: administer and detect isotopic tracers.
 10. Collect and preserve whole specimens.
 11. Dissect and freeze specimens with dry ice or LN_2.

3.8 SCHEDULES

Estimates of the development time for the experiments described in this FPE are shown in Table 3-9.

Table 3-9. Development Schedule

		1	2	3	4	5	6	YEARS
3.4.1.1	Metabolism and Energetics in Hypogravity	———	———	———	———			
2	Plant Growth at Low-g Level	———						
3	Orbital Growth of Dicotyledonous Seedlings	———	———	———	———	- - -	- - -	
4	Biochemical and Biorhythmic Changes in Plants due to Reduced Gravity	———						
5	The Effects of Weightlessness on Gamatogenesis and Morphogenesis in Gametophytes	———						
3.4.2.1	The Physiological Response of Plants to a Hypogravity-Gradient Environment	———	———	———				
2	Growth Transients in Roots Exposed to a Weightless Environment	———	———	———				
3.4.3.1	Low-g Effects on Tradescantia	———	———	———	———			
2	Effects of UV Irradiation on Mitotic Recombination in Weightlessness	———	———	———	———	- - -	- - -	

3.9 PRELAUNCH SUPPORT AND GSE

A common-use Life Sciences laboratory is required at the launch area to support the experiment packages and, in most cases, maintain sterility. It is suggested that this facility be sufficiently comprehensive to allow all the Principal Investigators and their research team to do all final assemblies and preparations.

A Life Sciences general ground control facility is required to provide a delayed simulation of the space bioresearch lab in terms of radiation, vibration, atmospheric composition, and man involvement. An optimum design is a duplicate facility of the space bioresearch lab, supported by the necessary radiation sources, mechanical actuation and bottle-gas inventory, operated on the ground for all biological control. Separation of the FPEs in the control facility can introduce additional variables.

The launch preparation facility and the ground control facility should be in the same complex. Direct link to mission control would provide communication with the space lab and the control facility and members of the experiment research staff.

3.10 SAFETY ANALYSIS

Safety hazards and precautions to be observed are shown in Table 3-10.

Table 3-10. Safety Analysis

HAZARDS	PRECAUTIONS
PLANT CONTAINERS	
Exposure to Container Atmosphere	Cage open operations performed in hooded work area Slight ΔP into cage
Leaks from Disconnects During Cage Removal From Manifold	Adequate air flow to move and trap particles and liquids Vacuum cleaner to collect and retain debris
Overpressurization of Cage Racks	Pressure relief valve
EXPERIMENTAL PROCEDURES	
Chemical Exposure	Work in hood area Purge capability Store chemicals in unbreakable containers Inert atmosphere Store in hermetically sealed cabinet which is purgable Emergency life support
Debris Exposure	Work in hooded work area Adequate air flow to EC/LS Emergency debris mask

3.11 AVAILABLE BACKGROUND DATA

The experiment data has been provided by NASA Ames Research Center, based on proprietary proposals received by NASA from Principal Investigators. Proposal data has been modified in some cases to fit the greater mission model provided by a general manned bioresearch laboratory as compared to Biosatellite missions.

VOLUME VIII

SECTION 4

CELLS AND TISSUES RESEARCH FACILITY

SECTION 4

CELLS AND TISSUES RESEARCH FACILITY

4.1 GOALS AND OBJECTIVES

This facility is to provide the basis for the definition and development of an orbital research facility and its operational and support requirements for the pursuit of research in space on single-celled organisms and tissues in culture. Research programs to be supported include a study of the growth, reproduction, morphology, biochemistry, and genetics of a wide variety of organisms.

The facility described here provides in-depth research capability with microorganisms and cells in tissue culture. Experiments provided here are selected to reflect the scientific requirements of the general facility and are not meant to be flown on any schedule. Identification of specific flight experiments can be accomplished when more information is available, such as the demands on the cell and tissue research facility by other FPEs, crew availability and skill, and experiment priority.

4.2 PHYSICAL DESCRIPTION

This FPE is a cluster of microbiological and tissue-culture experiment modules grouped together on the basis of commonality in equipment requirements, support requirements, research approaches, and specimen handling and observation techniques. The facility will require use of the radiobiology and specimen return units and the research centrifuge as well as the CORE units. It will provide the capability of maintaining uncontaminated cultures of cells and tissues for long periods of time. Basically, it may be considered to consist of two portions: 1) the zero-g experiments area, and 2) the onboard research biocentrifuge.

The zero-g experiment area will be sized to accommodate the experiments and appropriate work space. It will be maintained at one Earth atmosphere, with appropriate temperature and humidity control systems to permit shirtsleeve handling of research organisms and glovebox operation for hazardous operations.

The experiments will be enhanced by an onboard centrifuge capable of providing constant levels of acceleration between 1-g equivalent and the lowest value practical to provide.

The facility utilizes two FPE-specific equipment units: 1) cells and tissue holding units - - a series of standard incubators capable of supporting experiment packages

for ECS, observations/measurements and operations; 2) the cells and tissue research support unit. ECS is provided by the Biology ECS or the supporting vehicle. The facility concept is illustrated in Figure 4-1.

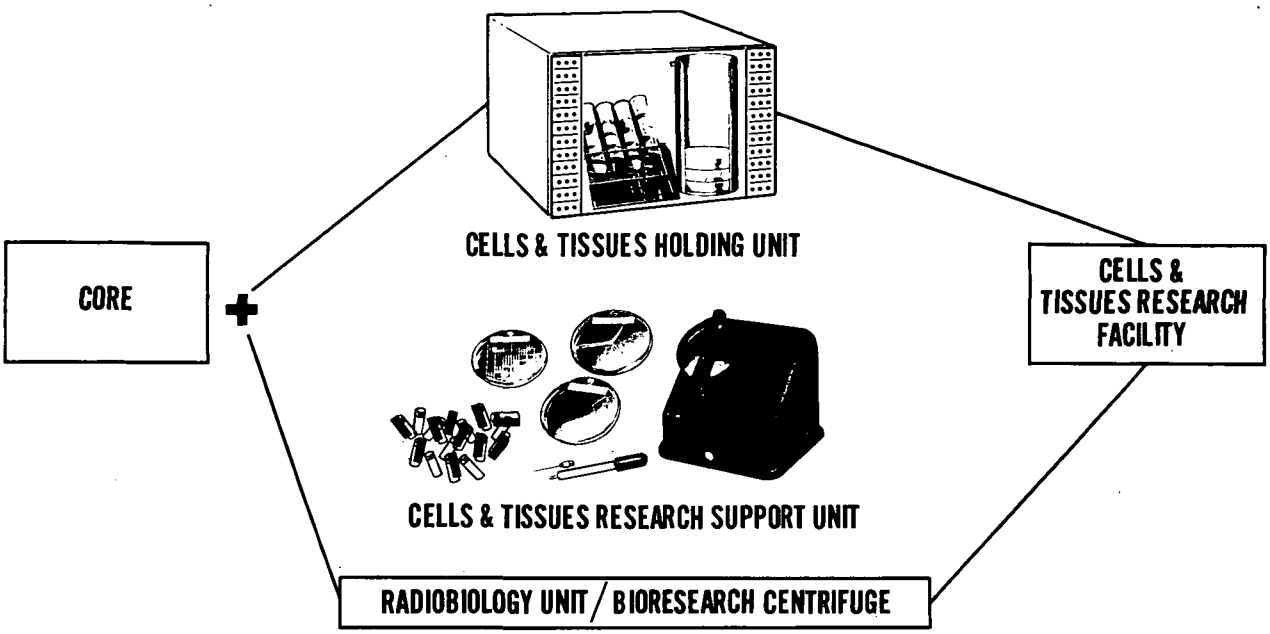


Figure 4-1. Life Sciences Cells and Tissues Research Facility

4.2.1 CELLS AND TISSUE HOLDING UNIT

4.2.1.1 Functional Capability. The function of the unit is to hold and support microorganism and cell culture stock and research organism. This unit is basically a series of incubators mounted at various temperatures. The incubators must support gas analysis or sampling and observation/measurement equipment and have windows for crew observation. The number of holding units, based on the cage rack model required for cells and tissue research, is dependent on the number of environmental parameters (specifically temperature and gravity) and the experiment-peculiar package envelope. Most cells and tissue experiment packages are small; however, video and cinemagraphic coverage increases the envelope 2 to 4 times. The following estimates provide 4 temperature levels in the labs and 4 temperature and g-level combinations in the centrifuge.

	Incubators	Volume (ea.)
Laboratory Only	4	0.14 m^3 (5 ft^3)
Laboratory + Centrifuge	8	0.14 m^3 (5 ft^3)

Incubators are common items and greater capacity can be obtained by sharing incubators among FPEs.

4.2.1.2 Description. The incubators may be standard holding units described for the general laboratory, measuring 65 cm (25.6 in) high by 65 cm (25.6 in) wide by 40 cm (15.8 in) deep. These standard units contain a rack for electronic plug-ins for the measurement transducers. Specific shelves are required to secure the various vials, bottles, dishes and electromechanical actuators required for cells and tissues research. Incubator specifications are:

	Incubator Range	Typical
Temperature 278 to 333°K	(5 to 60°C)	298±1°K 310±1°K 329±1°K (25±1°C) (37±1°C) (56±1°C)
pO_2		160 ± 5 mm
pN_2		600 ± 20 mm
pCO_2		<3 mm
Total Pressure		760 ± 20 mm
Relative Humidity	60 - 100%	95 ± 5%
Noise	TBD	
Vibration	TBD	
Offensive or Noxious Odors	TBD	

Table 4-1 is an equipment list for the unit, and Table 4-2 is an equipment-unit summary.

Table 4-1. Cells and Tissues Holding Unit Equipment List

Name	Performance Characteristics	Power W	Weight kg(lb)	Volume $m^3(ft^3)$
Standard Holding Units	See Section 4.2.1.2	10	27(60)	0.16(5.6)
Holding Unit Lighting (Values for one unit)	To provide 90 ± 10 ft-c through light diffusers; must dissipate heat from light	40	1(2.2)	0.003(0.1)

4.2.2 CELLS AND TISSUE RESEARCH SUPPORT EQUIPMENT

4.2.2.1 Functional Capability. This unit provides an inventory of supplies and transducers required to accomplish cells and tissue research. It is a rack and

Table 4-2. Equipment Unit Summary

	Laboratory Only	Laboratory + Centrifuge
OPERATOR SKILL		
POWER, AC		
average, watts	160	320
peak, watts		
peak duration, hr/day		
POWER, DC		
average, watts	40	80
peak, watts		
peak duration, hr/day		
WEIGHT, kg (lb)	150(330)	300(660)
ENVELOPE		
volume, m^3 (ft^3)	1(35)	2(70)
height, cm (in.)	TBD	TBD
width or diam, cm (in.)	TBD	TBD
depth, cm (in.)		
DATA		
voice, hr/day	TBD	TBD
TV, B&W, hr/day		
TV, color, hr/day		
analog, MHz	4(1.3 hr/day)	4(1.3 hr/day)
digital, bps	410	410

cabinet system to store hardware and transducers required for research procedures and automatic measurement techniques, an electronic rack system along one side to support the electronic modules associated with the specific ion sensors, and general transducers for cells and tissue research.

4.2.2.2 Description. This unit will store and contain various items, especially culture containers (dishes, vials, bottles and test tubes), an assortment of dehydrated substrates or prepared substrates, specimen transfer devices (probes, loops and pipettes), and all experiment-specific equipment. Table 4-3 is an equipment list, and Table 4-4 is an equipment-unit summary.

Table 4-3. Equipment List

Name	Lab Only			Lab + Centrifuge		
	Pwr W	Wt. kg (lb)	Vol. m^3 (ft^3)	Pwr W	Wt. kg (lb)	Vol. m^3 (ft^3)
Rack and Cabinet System	0	34 (75)	0.5 (17.5)	0	41 (90)	0.75 (26)
Miscellaneous Hardware	0	11 (25)	0.1 (3.5)	0	16 (35)	0.1 (3.5)

4.3 EXPERIMENT REQUIREMENTS SUMMARY

Experiment requirements are summarized in Tables 4-6, 4-7, and 4-8.

4.4 EXPERIMENT PROGRAM

The cells and tissues research program is comprised of a group of representative experiment classes, each supported by a group of representative experiments. Within each class at least the first of the representative experiments is described in detail; other representative experiments are given by title and experiment requirements data only. These selected representative experiments provide experiment support requirements and other spacecraft and mission impacts to a level ample to characterize the requisite Cells and Tissues Research Facility. Table 4-5 ennumerates the representative experiment classes and representative experiments which scope the experiment program.

4.4.1 ROLE OF GRAVITY IN LIFE PROCESSES OF MICROSCOPIC ORGANISMS AND CULTURED TISSUES. The objectives of this experiment class are:

a. To discern the role gravity plays in the cellular functions of growth and replication by observing cultured free cells and tissues in a hypogravity environment.

b. To discern whether cultured cellular and tissue development, structures and functions are altered by the space environment.

Table 4-4. Equipment Unit Summary

	Laboratory Only	Laboratory + Centrifuge
OPERATOR SKILL		
POWER, AC		
average, watts	0	0
peak, watts		
peak duration, hr/day		
POWER, DC		
average, watts	0	0
peak, watts		
peak duration, hr/day		
WEIGHT, kg (lb)	45(100)	55(120)
ENVELOPE		
volume, m^3 (ft^3)	2.9(100)	3.45(120)
height, cm (in.)	TBD	TBD
width or diam. cm (in.)	TBD	TBD
depth, cm (in.)	TBD	TBD
DATA		
voice, hr/day	TBD	TBD
TV, B&W, hr/day		
TV, color, hr/day		
analog, MHz		
digital, bps	0	0

c. To observe variations in adaption to the space environment.

d. To develop capability to predict extent of cellular variability, if any, as a function of time in the space environment.

Experiment requirements are summarized in Table 4-6.

Table 4-5. Cells and Tissues Research Facility

Section	Title
4.4.1	Experiment Class: Role of Gravity in Life Processes of Microscopic Organisms and Cultured Tissues
4.4.1.1	Experiment: Effect of weightlessness on life processes of small organisms
4.4.1.2	Experiment: Effect of weightlessness, space vacuum and radiation on soil sample integrity and viability during long-term storage and preservation
4.4.1.3	Experiment: Effect of weightlessness on morphogenesis and embryogenesis in cultured somatic cells
4.4.1.4	Experiment: Effects of weightlessness on the morphology, histology and biochemistry of bone tissue cultures
4.4.1.5	Experiment: Effects of the space environment on periodicity of growth and conidial information in fungi
4.4.1.6	Experiment: Effect of weightlessness on functional and developmental stability of vertebrate embryos
4.4.1.7	Experiment: Effects of weightlessness and hormones on bone culture mineral metabolism
4.4.1.8	Experiment: Effects of weightlessness on the calcium metabolism of human cells in tissue culture
4.4.2	Experiment Class: Effect of the Space Environment in Genetic, Subcellular and Molecular Phenomena
4.4.2.1	Experiment: Effects of weightlessness on chromosomes and nuclei acid synthesis of human tissue cultures
4.4.2.2	Experiment: Effects of weightlessness on molecular reactions of biological interest
4.4.2.3	Experiment: Effect of the space environment on the rate of mutation of radiation resistant microorganisms
4.4.3	Experiment Class: Role of Gravity in Interspecies Relationships
4.4.3.1	Experiment: Effects of weightlessness on plant tumor tissues
4.4.3.2	Experiment: Effects of space environment on insect viruses and virus infected insects
4.4.3.3	Experiment: Effect of hypogravity on host/parasite relationships in bacteria

Table 4-6. Experiment Requirements Summary (Class: The Role of Gravity in Life Processes of Microscopic Organisms and Cultured Tissue)

EXPERIMENT NO. AND TITLE	4411 Effect of Weightlessness on Life Processes of Small Organisms		4412 Effects of Weightlessness, Space Vacuum and Radiation on Soil Sample Integrity and Viability during Long-Term Storage and Preservation		4413 Effect of Weightlessness on Morphogenesis and Embryogenesis in Cultured Somatic Cells		4414 Effects of Weightlessness on the Morphology, Histology & Biochemistry of Bone Tissue Cultures		4415 Effects of the Space Environment on Perodicity of Growth and Conidial formation in Fungi		4416 Effect of Weightlessness on Functional & Developmental Stability of Vertebrate Embryos		4417 Effects of Weightlessness and Hormones on Bone Culture Mineral Metabolism		4418 Effects of Weightlessness on the Calcium Metabolism of Human Cells in Tissue Culture		NOTES
SPECIMEN	Frog Eggs				Carrot or Parsnip Tissue Culture		Chick Embryo Limb Bone Cultures		Neurospara		Chicken or Japanese Quail Eggs		Rat Thyroid & Parathyroid & Mouse Bone Tissue		Human Diploid Cells Embryonic lung or kidney		
LOCATION	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	
NO. OF SPECIMENS	24	48	60	120	10	20	20	40	32	64	32	64					
HOLDING CAGES Standard Metabolic Colony	24	48	60	120	10 Vials 1 liter	20 Vials 1 liter			Dishes	Dishes	Egg Holders	Egg Holders	20 bottles	40 bottles	10 bottles	20 bottles	[1] No periodic cues at whole-number fractions of 24 hours.
MAN REQUIREMENTS, hr Skill 1 Setup	4	8	4	8	4	8	4	8	4	8	4	8	2	4	2	4	[2] Normal Laboratory Max.: 10^{-3}g 90% of time 10^{-2}g 10% of time
Daily Average	0.5	1	0.5	1	0.5	1	0.5	1	0.5	1	1	2	0.5	1	0	0	
Terminate	4	8	4	8	4	8	4	8	4	8	4	8	2	4	2	4	
Skill 2 Setup																	[3] Ad Hoc observations required up to 8 hr/day. They cannot be scheduled and are part of the daily average. Crew time is average.
Daily Average	0.1	0.2	0.1	0.2	0.1	0.2	0.1	0.2	0.2	0.4	0.2	0.4	0.1	0.2			
Terminate																	
Skill 3 Setup																	[4] SMAC = Space maximum allowable concentration for man.
Daily Average			0.5	1									0.5	1			
Terminate																	
EXPERIMENT DURATION, days	180	180	180	180	60	60	10	10	90	90	90	90	14	14	42	42	[5] No offensive or noxious odor.
ENVIRONMENTAL REQMTS pO_2, mm Hg	150±10	150±10											150±10	150±10			[6] TBD; minimal to reasonable engineering design effort.
Total Pressure, mm Hg	760±10	760±10	TBD	TBD	760±10	760±10	760±10	760±10	760±10	760±10	760±10	760±10	760±10	760±10	760±10	760±10	
pCO_2, mm Hg	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	[7] Arterial & Venous
pCO, mm Hg	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	[8] Includes blood, feces, urine, bacterial, gas, and biopsy samples.
pNH_3, mm Hg	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.03	<0.03	<0.01	<0.01	<0.01	<0.01	
pH_2O, mm Hg	NA	NA	NA	NA	NA	NA	NA	NA	42±5	42±5	40±5	40±5	40±3	40±3	17±2	17±2	
Temperature, °K (°C)	291±1 (18±1)	291±1 (18±1)	TBD	TBD	Ω	Ω	T	T	T	T	T	T	T	T	Δ	Δ	[9] Samples per week/ tests per sample
O_2 Consumption, kg/day	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	[10] Measurements made at holding unit level only; () = each organism.
CO_2, kg/day	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	
Noise, dB	[6]	[6]	[6]	[6]	[6]	[6]	[6]	[6]	[6]	[6]	[6]	[6]	[6]	[6]	[6]	[6]	
Vibration, g (Hz)	[6]	[6]	[6]	[6]	[6]	[6]	[6]	[6]	[6]	[6]	[6]	[6]	[6]	[6]	[6]	[6]	
Acceleration, g	[11]	[11]	[11]	[11]	[11]	[11]	[11]	[11]	[11]	[6]	[6]	[6]	[6]	[6]	[6]	[6]	[11] Vibration maximum allowable 10^{-5} 90% of time, 10^{-4} 10% of time
Radiation, C/kg	TBD	TBD	TBD	TBD	[6]	[6]	[6]	[6]	[6]	[6]	[6]	[6]	[6]	[6]	[6]	[6]	
Illumination, lum/m^2 (ft-c)			970±100 (90±10)	970±100 (90±10)	970±100 (90±10)	970±100 (90±10)											N = Negligible
Trace Contaminants																	
NUMBER AND FREQUENCY OF MEASUREMENTS																	Ω - 293.5 ±0.5 (20.5 ±0.5)
																	T - 310.5 ±0.5 (37.5 ±0.5)
																	Δ - 295.5 ±0.5 (22.5 ±0.5)

Table 4-6. Experiment Requirements Summary (Class: The Role of Gravity in Life Processes of Microscopic Organisms and Cultured Tissue), Contd

EXPERIMENT NO.	4411		4412		4413		4414		4415		4416		4417		4418		NOTES
LOCATION	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	
NUMBER AND FREQUENCY OF MEASUREMENTS																	
Number and Frequency of Measurement																	
pO_2, hourly	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	
pCO_2, hourly [10]	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	
pNH_3, hourly [10]													1	2			
pH_2O, hourly [10]													1	2	1	2	
Temp., hourly [10]	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	
Noise, continuous [10]													1	2			
Vibration, cont. [10]																	
Acceleration, cont. [10]	1	2	1	2	1	2	1	2	1	2	1	2	1	2			
Radiation, cont. [10]			1	2									1	2			
Organism Sacrifice/wk	10	20	10	20													
Urine Analysis/wk																	
Organism Visual Monitorings/wk																	
Organism Recovery Preparation, No.																	
Organism Live Recovery, No.																	
Illumination, No./meas.																	
Radiobiologies/wk																	
Total Pressure, mm Hg	1	2	1	2	1	2	1	2	1	2	1	2					
Photography	100	200	50	100													
Event Verification No/day Avg.	10	20	10	20			20	40	4	8	8	16			1	2	
Substrate pH Msmts/day			20	40									20	40			
Histologies [9]											8/12	8/12					
Biochemistries [9]											8/10	8/10	18/2	18/2			
Liquid Samples No/day													18	36			
Replace substrate or subculture No/week	72	144	20	40			60	120	96	192			60	120	20	40	
Sample preservation No/week													125	250			
POWER																	OTHER
AC																	
Continuous, watts	6	12	15	30	15	30	30	60	15	30	30	30	20	40	25	50	
Peak, watts							50	50							40	80	
Peak Duration, hrs/day							8	8							1	1	
DC																	
Continuous, watts	8	8	5	10	5	10	5	10	5	10	5	10	10	20	5	10	
Peak, watts																	
Peak Duration, hrs/day																	
WEIGHT																	
Organisms and Cages, kg (lb)	20 (44)	40 (88)	40 (88)	80 (176)	11 (24)	22 (48)	20 (44)	40 (88)	10 (22)	20 (44)	20 (44)	40 (88)	20 (44)	40 (88)	30 (66)	60 (132)	
Ancillary Research Equipment, kg (lb)	40 (88)	80 (172)	40 (88)	80 (176)	2 (4.4)	4 (8.8)	20 (44)	40 (88)	5 (11)	10 (22)	10 (22)	20 (44)	5 (11)	10 (22)	5 (11)	10 (22)	
VOLUME																	
Organisms and Cages, m^3 (ft^3)	0.15 (5.3)	0.3 (10.6)	0.1 (3.5)	0.2 (7)	0.15 (5.3)	0.35 (10)	0.05 (1.7)	0.1 (3.5)	0.05 (1.7)	0.1 (3.5)	0.2 (7)	0.4 (14)	0.02 (0.7)	0.04 (1.4)	0.03 (1.1)	0.06 (2.1)	
Ancillary Research Equipment, m^3 (ft^3)	0.1 (3.5)	0.2 (7)	0.1 (3.5)	0.2 (7)	0.1 (3.5)	0.1 (3.5)	0.2 (7)	0.4 (14)	0.1 (3.5)	0.2 (7)	0.1 (3.5)	0.2 (7)	0.01 (0.35)	0.02 (0.7)	0.01 (0.35)	0.02 (0.7)	
LOGISTICS																	
Weight at Launch, kg (lb)	70 (154)	140 (308)	70 (154)	140 (308)	27 (60)	27 (60)	41 (90)	81 (178)	16 (35)	31 (68)	31 (68)	61 (134)	26 (58)	51 (113)	36 (80)	61 (136)	
Supplies/Mo. Up, kg (lb)	10 (22)	20 (44)	5 (11)	10 (22)	1 (2.2)	1 (2.2)	1 (2.2)	1 (2.2)	1 (2.2)	1 (2.2)	1 (2.2)	1.5 (3.3)	1 (2.2)	1 (2.2)	1 (2.2)	1 (2.2)	
Supplies/Mo. Down, kg (lb)	8 (17.6)	16 (35)	10 (22)	20 (44)	0.8 (1.8)	0.8 (1.8)	0.8 (1.8)	0.8 (1.8)	0.8 (1.8)	0.8 (1.8)	0.8 (1.8)	1.2 (2.7)	0.8 (1.8)	0.8 (1.8)	0.8 (1.8)	0.8 (1.8)	
Weight at Termination, kg (lb)	60 (132)	120 (264)	60 (132)	120 (264)	25 (55)	25 (55)	40 (88)	80 (172)	15 (33)	30 (66)	30 (66)	60 (132)	25 (55)	50 (110)	35 (77)	60 (132)	
Volume at Launch, m^3 (ft^3)	0.25 (8.8)	0.5 (17.5)	0.25 (8.8)	0.5 (17.6)	0.25 (8.8)	0.4 (14)	0.25 (8.8)	0.5 (17.5)	0.15 (5.3)	0.3 (10.5)	0.3 (10.5)	0.6 (21)	0.01 (0.35)	0.02 (0.7)	0.04 (1.4)	0.08 (2.8)	
Supplies/Mo. Up, m^3 (ft^3)	0.02 (0.7)	0.04 (1.4)	0.02 (0.7)	0.04 (1.4)	0.01 (0.35)	0.01 (0.35)	0.01 (0.35)	0.01 (0.35)	0.02 (0.7)	0.02 (0.7)	0.02 (0.7)	0.02 (0.7)	0.01 (0.35)	0.01 (0.35)	0.01 (0.35)	0.01 (0.35)	
Supplies/Mo. Down, m^3 (ft^3)	0.02 (0.7)	0.03 (1.1)	0.02 (0.7)	0.04 (1.4)	0.01 (0.35)	0.01 (0.35)	0.01 (0.35)	0.01 (0.35)	0.01 (0.35)	0.02 (0.7)	0.01 (0.35)	0.02 (0.7)	0.01 (0.35)	0.01 (0.35)	0.01 (0.35)	0.01 (0.35)	
Volume at Termination																	
Frozen Specimens Down			X	X					X	X	X	X	X	X	X	X	
Live Organisms Up	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
Live Organisms Down							X	X									
Frozen Specimens Up			X	X													
Other																	
Preserved Specimen Down					X	X	X	X			X	X					
COMMUNICATIONS																	
Voice, hr/day	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD			
TV, B&W, hr/day	X	X	X	X	X	X	X	X	X	X	X	X	X	X			
TV, Color, Ad Hoc	X	X	X	X	X	X	X	X	X	X	X	X	X	X			

4.4.1.1 Effect of Weightlessness on Life Processes of Small Organisms

4.4.1.1.1 Scientific Objective. The principal objective is that of studying the effect of weightlessness on the sequentially exposed unfertilized, fertilized egg and embryo of the frog, Rana pipiens. Normality of division, differentiation and development under 0-g and fractional-g forces will be studied grossly and microscopically.

4.4.1.1.2 Description. This experiment may be implemented by one of two modes: 1) automated or semi-automated (astronaut command); 2) nonautomated. The choice of method will depend upon the following considerations:

	Advantages	Disadvantages
a. Automated or semi-automated	1. allows for appropriate controls 2. more "astronaut-proof" 3. can be treated as package 4. background of experience	1. expensive 2. finite hold-time 3. materials testing problems 4. cooling cycle necessary
b. Nonautomated	1. less expensive 2. fresher material available for 0-g exposure 3. greater hold-time tolerance 4. cooling cycle unnecessary 5. extended lifetime 6. increased sample size	1. extensive scientist-astronaut training 2. appropriate controls problematical (a major problem) 3. 0-g operation problematical

The experiment apparatus for the automated or semi-automated mode will consist of four modules of three units each. Each module will be capable, by command or astronaut manipulation, of fertilizing, rinsing, maintaining and fixing (preserving) operations. Unfertilized frog eggs (20/unit) will be maintained in the craft prior to launch at low temperature, 278°K (5°C), attached to filter paper soaked in a physiological salt solution. Beyond 12-13 hours of hold-time, fertilizability begins to fall

off, affecting the experiment value proportionally with time thereafter. After attainment of weightlessness, the eggs will be fertilized by frog sperm upon command (or by program if semi-automated). Appropriate actuations will follow. The four modules may each be actuated separately to allow for fixation at appropriate life cycle stages.

The material must be controlled at about 291°K (18°C). To return animals alive, a possible desideratum, the experiment has a lifetime of 4-5 days. However, fixation of specimens will permit an indefinite lifetime. The experiment will be dependent upon the CORE for temperature readout (1 thermistor/module), actuation commands, and command verifications.

The following data applies to the total package:

Weight	27 kg (60 lb)
Volume	0.15 m^3 (5.3 ft^3)
Dimensions	53 x 53 x 53 cm (21 x 21 x 21 in)
Power	8 Watts

The nonautomated manner of operation would involve extensive training and considerable time of a designated astronaut and would take full advantage of a manned laboratory mission. At least two gravid frogs, preselected for quality of donor eggs, and a sperm solution would comprise the basic biological material. Conceivably, mission restrictions permitting, a number of male and female frogs could be flown and operations ordinarily performed on the ground could be performed in space. However, the former case, with fewer variables, will be considered.

In addition to the biological material, supporting hardware and solutions are also necessary. Medium, to be used for maintenance and rinsing (after fertilization), and fixative must be available. A method of containing the eggs for subsequent operations after extracting them from the female frog must be devised.

The following data applies to experiment-peculiar equipment (package of hardware, containers, solutions):

Weight	27 kg (60 lb)
Volume	0.25 m^3 (8.8 ft^3)
Dimension	61 x 61 x 61 cm (2 x 2 x 2 ft)
Power	0

The experiment will be dependent upon the CORE for voice command verification, manual temperature readout transcription, and possibly certain common-use equipment (thermometers, microscope, etc.).

4.4.1.3 Observation/Measurement Program

a. Automated or semi-automated mode:

 1. Read-out four temperature channels as many as 40 times a day. (Hard-line readout required on pad).

 2. Verify commanded or programmed actuations as required (2-3 per mission).

b. Nonautomated mode

 1. Record temperatures as above.

 2. Verify fertilizing, rinsing and fixing operations.

 3. Maintain organisms (feeding, medium changing) if experiment exceeds 5-7 days beyond fertilization.

 4. Observe and record developmental stages in extended experiment.

4.4.1.1.4 Interface, Support and Performance Requirements. General environment requirements are:

Temperature:	291 ±1°K (18 ±1°C)
Relative Humidity:	N/A
Total Pressure:	N/A
O_2N_2 Ratio:	20% - 80%
Other Gases:	Normal Atmospheric
Thermal Output:	TBD.

Unique environment requirements are:

Acceleration:	Anything above 10^{-5}g undesirable, particularly during period of fertilization
Vibration:	Minimal (but eggs relatively resistant)
Rhythmic phenomena:	TBD (but probably nonsensitive)
E-M phenomena:	TBD (but probably nonsensitive).

Power required is 80 W, average.

Data management requirements are:

Command:	by ground to air, signal or voice	Mode 1
	by program	Mode 2
Readout:	Temperature by analog (40 times per day) Voice record tapes (Mode 1, about 12 critical operations; Mode 2, up to 100 critical operations & observations)	

Crew support requirements are:

Experiment setup:	Mode 1, negligible; Mode 2, 2 hr (1/mission).
Research activities:	Mode 1, negligible. Mode 2, photography about 1/2 hr. every 2nd day for mission (about 15 pictures/event); visual observations about 1 hr. every 2nd day for mission; maintenance about 1/2 hr. twice a week for mission; experiment termination, 1 hr/event and 3-4 events/mission.
Skill level:	Mode 1, minimal; Mode 2, well-trained scientist-astronaut or technician.

Orbital altitude and inclination: N/A

Prelaunch and launch requirements are provision of laboratory space and facilities, maintenance of environmental requirements, and hardware maintenance and preparation support.

4.4.1.1.5 Potential Role of Man. The nonautomated mode of this experiment's implementation will of course require major involvement of an astronaut-scientist or technician. He must be knowledgeable of normal frog egg development and therefore be able to recognize abnormal development. He must be trained in the care and feeding of frog larvae. He must learn to operate well the provided hardware in egg handling, fertilizing, fixing, observing and photographing. He must be especially proficient in record keeping. To ensure unquestioned results, he must enjoy in these measures the full confidence of the principal investigator. He should, in short, possess talents that would qualify him as a co-investigator.

The following may be representative of man's specific duties in preparing and implementing the experiment in space. He will be expected to follow a checklist in detail, by time-line, after having performed these functions many times previously on the ground.

a. Inject about 10 female frogs each with 3-4 female pituitary glands excised from sacrificed frogs; maintain separately at S/C temperature.

b. Twenty-four hours later, sacrifice about 10 male frogs, excise testes and macerate in spring water (5 cm^3 H_2O/2 testes).

c. Strip eggs from female frogs (about 50 from each) into small individual plates and fertilize with the sperm solution.

d. Wash sperm from eggs and refill plates with spring H_2O.

e. Using microscope from CORE, observe over next 7-8 hours.

f. Select at least two donor frogs from the ten females injected on the basis of apparently normal development during these early stages (providing development does proceed normally; abnormalities may appear later because of this early exposure to 0-g).

g. Prepare a number of experimental containers (allowing at least 10 cm^3 water for every 5 eggs), fertilize and rinse, using these selected frogs. Maintain at 291°K (18°C) in incubator provided by CORE.

h. Fix and preserve samples (fix with glutaraldehyde, preserve with alcohol series) over next 5 days at prescribed intervals. Observe and record stages of development.

i. If feasible, maintain developing embryos beyond 5 days until end of mission. This means frequent feeding (dried lettuce) and cleaning (changing) medium.

j. At conclusion of mission, transfer fixed and live specimens to transport containers, exercising care in protection from environmental extremes.

4.4.1.1.6 Available Background Data. An experiment proposed for manned space flights (NASA Form 1346) and biosatellite implementation plan (NASA Form 1346) have been submitted. The experiments were proposed and flown on Gemini flights 8 and 12 and on Biosatellites 1 and 2.

4.4.1.2 Effects of Weightlessness, Space Vacuum and Radiation on Soil Sample Integrity and Viability During Long-Term Storage and Preservation.

4.4.1.2.1 Scientific Objective. The principal objective is to determine the effects of the space environment on soil abiotic (physical and chemical) and biotic (microbial or other organic) properties, especially at the microbial level, including indigenous, introduced, and isolated microorganisms at various temperatures, moisture activities (stresses), and gas phases (concentrations and pressures). The objectives are proposed in consideration of 1) the need to know the influences of the space environment on soil sample viability and integrity during return of a sample from extended space missions, such as from Mars, and 2) changes that may occur in soil properties, especially the activation of microbiota, at various moisture and gas conditions while subjected to the space environment.

4.4.1.2.2 Description. The specimens will include soil samples and microbial isolants aseptically procured from harsh terrestrial environments (hot and cold deserts, volcanic areas, high mountains, polar permafrost), and contamination sources (human). Soils will represent weathered to relatively unweathered viable materials of known composition and properties. The microorganisms will include indigenous or nonindigenous, single or mixed populations of bacteria (including streptomycetes), algae, fungi (yeasts and molds), and protozoa. Common human microbial contaminants also will be included in the experiments, either singly or in combination with various other microbiota. The soils and microorganisms will be chosen on the basis of their prevalence, adaptability, activity, and ecological sequence of development or survivability in natural or simulated harsh environments.

The experiment samples will be confined in chambers of $\leq 4 \times 4 \times 4$ cm ($1.6 \times 1.6 \times 1.6$ in.) dimensions. (Design and configuration TBD.) Samples or isolants exposed to ambient space environment will be contained in sturdy, vacuum-resistant chambers of sterilizable inert material having pore sizes of $\leq 10^{-7}$ m diameter. Other samples or isolants will be in pressurized, water-tight glass containers (design and configuration TBD).

The experiment apparatus will consist of 5 sample chambers in 12 modules, to be exposed concurrently to conditions of ambient space environment, and interface support requirements of temperature and light. Soil samples or isolated microorganisms showing changes or activity during flight will be examined visually, microscopically, chemically, and physically, including instruments (TBD) for growth, reproduction, and survivability of microbiota. Some samples will be maintained or preserved for 24 hours to 5 days and prepared for immediate examination. Other samples will be preserved and examined intermittently for periods up to 6 months.

Experiment variables will include space environment (ambient) conditions and the following controlled conditions:

Temperature: 78°K to 310°K (-195°C to 37°C)

Total pressure: 1.33×10^{-6} N/m^2 to one earth atmosphere

Gases: O_2, N_2, A, CO_2, CO, and others

Moisture activities: 10^4 to 10^{-4} atmospheres

Light: Daylight fluorescent, 275 to 1100 lum/m^2 (25.5 to 102 ft-c)

Temperature-Light/Dark Cycles: TBD.

Total package weight, volume, and envelope are:

Weight	40 kg (88 lb)
Volume	0.1 m^3 (3.5 ft^3)
Envelope	43 × 43 × 53 cm (17 × 17 × 21 in.)

4.4.1.2.3 Observation/Measurement Program. Observations and analyses will be made during flight and at the end of the experiment, dependent upon crew skills and availability. Visual and analytical measurements will be made for abundances, kinds, shifts of populations, and activities and metabolic functions of bacteria, yeasts, molds, algae and protozoa. Soil physical and chemical measurements will be made for changes in structure, cohesion, aggregation, pH, chemical ions and substrate transformations (e.g., nitrite, nitrate, sulfide, sulfate, and phosphate), gases (e.g., methane and carbon dioxide production), and nitrogen fixation. Any visual changes, such as growth of algae, will be photographically recorded.

4.4.1.2.4 Interface, Support and Performance Requirements. General environmental requirements are:

Temperature: Space ambient 310°K, 293°K, 283°K, 278°K, 268°K, 243°K, 193°K, 78°K (37°C, 20°C, 10°C, 5°C, -5°C, -30°C, -80°C, -195°C).

Relative Humidity: Space ambient, N/A.

Total Pressure: Space ambient, Earth atmosphere.

O_2N_2 Ratio: N/A.

Thermal Output: Space ambient, 15W continuous.

Unique environmental requirements are rhythmic phenomena: Diurnal temperature and light/dark cycles.

Readout requirements are temperature, light, sample moisture and gases, and space ambient.

Crew support requirements are manual movement of samples for diurnal cycles in environmental chambers, unless automated.

Reentry and post-reentry requirements are maintenance of environmental requirements, especially temperature, and vacuum; return of samples exposed to ambient; and return of hardware as soon as possible to experimenter.

4.4.1.2.5 Potential Role of Man. The versatile nature of this experiment provides for considerable leeway in the need for manned participation. Samples exposed to ambient space environmental conditions will require minimum care. Samples preserved in sealed containers under controlled environments will not necessarily require any flight experimentation to provide useful data at the end of the experiment. However, the value of the experiment is greatly increased if certain elements of the CORE are used, and the most active samples can be withdrawn at intervals, observed, and analyzed. This experiment has the potential of obtaining increasingly useful data with the increase in appropriate support and manned participation during a mission with an indefinite period.

4.4.1.2.6 Available Background Data. Experimental results used in the development of this research program were obtained from field and laboratory studies of harsh terrestrial environments, especially the soil microbial ecology of temperate, volcanic, high mountain and polar deserts. Additional results have been obtained from the long-term study of desert soils and microorganisms subjected to variables of vacuum, moisture, temperature and gases.

4.4.1.2.7 Schedule. The estimated development time for the experiment described in this FPE is 5 years.

4.4.1.3 Effect of Weightlessness on Morphogenesis and Embryogenesis in Cultured Somatic Cells. The experiment objective is to determine whether free plant cells will divide and grow in an organized way at, or near, zero gravity, in comparison with the morphogenesis they display under conditions of neutralized gravity (clinostats) in the laboratory.

4.4.1.4 Effects of Weightlessness on the Morphology, Histology, and Biochemistry of Bone Tissue Cultures. This experiment is to identify the mechanisms underlying the loss of calcium in bone tissue of organisms subjected to periods of weightlessness.

4.4.1.5 Effects of the Space Environment on Periodicity of Growth and Conidial Formation in Fungi. The objective of this experiment is to detect specific rhythm environment coupling for fungi and explore the mechanism of this coupling.

4.4.1.6 Effect of Weightlessness on Functional and Developmental Stability of Vertebrate Embryos. This experiment's objective is to detect the effect of weightlessness and radiation combined weightlessness on avian embryos.

4.4.1.7 Effects of Weightlessness and Hormones on Bone-Culture Mineral Metabolism. The objective of this experiment is to determine if bone mineral loss in a weightless state occurs from the environment, the parathyroid gland, the thyroid C cells or combinations of these effects.

4.4.1.8 Effects of Weightlessness on the Calcium Metabolism of Human Cells in Tissue Culture. The objective of this experiment is to determine if the mechanism of calcium loss in humans in weightlessness is at a cellular or higher level of physiological organization.

4.4.2 EFFECT OF THE SPACE ENVIRONMENT IN GENETIC, SUBCELLULAR AND MOLECULAR PHENOMENA. Experiment class objectives are:

a. To establish whether the space environment significantly alters the genetic coding mechanisms.

b. To describe the interaction of the space environment with subcellular structure and function.

c. To investigate biochemical phenomena, such as enzyme kinetics, in the weightless state.

d. To investigate environmental factors in control of rhythmical phenomena in micro-organisms by the removal of these factors in the space environment.

Table 4-7 is an experiment requirements summary for this experiment class.

4.4.2.1 Effects of Weightlessness on Chromosomes and Nucleic Acid Synthesis of Human Tissue Cultures

4.4.2.1.1 Scientific Objective. The main objective of this experiment is to study the effect of weightlessness alone and weightlessness together with radiation on chromosomes, nucleic acid synthesis, and cell growth patterns of human lymphocytoid cells and turtle cells. Previous biospace experiments seem to indicate that weightlessness alone has no mutagenic effect and radiation combined with weightlessness does not give significant synergetic effect. Nevertheless, definite proof to these points is still lacking. It is possible that weightlessness may affect behavior of mitosis, growth pattern, and DNA and RNA synthesis which, in turn, may have mutagenic effect. If so, synergism of weightlessness and radiation would be expected.

4.4.2.1.2 Description. Due to the complexity of short-term human white cell cultures, results on chromosome damage induced by physical agents usually vary. Hence, 12 long-term human lymphocytoid cell lines chosen from over 450 lines will be used. Since reptiles are known to resist radiation more than higher vertebrates, two turtle cell lines will be included. There will then be a total of 14 cell lines used (12 human, 2 turtle), all currently available.

In design, two groups of experiments will be conducted: a study of the effects of weightlessness alone and a study of the combined effect of weightlessness and radiation. To this end, four identical groups of the 14 cell lines will be flown, three groups exposed to an onboard gamma radiation source and the fourth unexposed. The experiment duration can be planned for 3 to 7 days, with some samples being

Table 4-7. Experiment Requirements Summary (Class: Effects of Space Environment on the Role of Gravity in Genetics, Subcellular and Molecular Phenomena)

EXPERIMENT NO. AND TITLE	4421 Effects of Weightlessness on Chromosomes and Nucleic Acid Synthesis of Human Tissue Cultures		4422 Effects of Weightlessness on Molecular Reactions of Biological Interest		4423 Effects of the Space Environment on the Rate of Mutation of Radiation-Resistant Microorganisms										NOTES
SPECIMEN	Human tissue culture & turtle tissue cultures		Enzymes and substrates		Microorganisms										
LOCATION	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	
NO. OF SPECIMENS															
HOLDING CAGES															
Standard	*	**	***	***	†	†									
Metabolic															
Colony															
MAN REQUIREMENTS, hr															
Skill 1															
Setup	2	4													
Daily Average [3]															
Terminate	2	4													
Skill 2															
Setup															
Daily Average [3]			4	8											
Terminate															
Skill 3															
Setup															
Daily Average [3]															
Terminate															
EXPERIMENT DURATION, days	7	7	1-90	1-90											
ENVIRONMENTAL REQMTS															
pO_2, mm Hg	150±10	150±10	150±10	150±10											
pN_2 or Total Pressure, mm Hg	760±10	760±10	760±10	760±10											
pCO_2, mm Hg	<3	<3	<3	<3											
pCO, mm Hg	<0.01	<0.01													
pNH_3, mm Hg	<0.01	<0.01													
pH_2O, mm Hg	20±2	20±2													
Temperature, °K (°C)	298±2 (25±2)	298±2 (25±2)	TBD	TBD											
O_2 Consumption, kg day	N	N	0	0											
CO_2, kg day	N	N	0	0											
Noise, dB	[6]	[6]	[6]	[6]											
Vibration, g (Hz)	[6]	[6]	[6]	[6]											
Acceleration, g	[2]	[2]	[2]	[2]											
Radiation, C/kg	[6]	[6]	[6]	[6]											
Illumination, lum/m^2 (ft-c)															
Trace Contaminants															
NUMBER AND FREQUENCY OF MEASUREMENTS															

[2] Normal Laboratory

Max.: 10^{-5} 90% of time; 10^{-4} 10% of time

[3] Ad Hoc observations required up to 8 hr/day. They cannot be scheduled and are part of the daily average. Crew time is average.

[4] SMAC = Space maximum allowable concentration for man.

[5] No offensive or noxious odor.

[6] TBD; minimal to reasonable engineering design effort.

[7] Arterial & Venous

[8] Includes blood, feces, urine, bacterial, gas, and biopsy samples.

[9] Samples per week/ tests per sample

[10] Measurements made at holding unit level only; () = each organism.

*10 dishes
**20 dishes
***20 bottles
†32 dishes

N = Negligible

Table 4-7. Experiment Requirements Summary (Class: Effects of Space Environment on the Role of Gravity in Genetics, Subcellular and Molecular Phenomena), Contd

EXPERIMENT NO.	4421		4422		4423										NOTES
LOCATION	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	
NUMBER AND FREQUENCY OF MEASUREMENTS															
Samples [8] Prep for Earth Return/wk															
pO_2, hourly	1	2													
pCO_2, hourly [10]	1	2													
pNH_3, hourly [10]															
pH_2O, hourly [10]	1	2													
Temp., hourly [10]	1	2													
Noise, continuous [10]			1 cont	2 cont											
Vibration, cont. [10]															
Acceleration, cont. [10]			1	2											
Radiation, cont. [10]															
Organism Sacrifice/wk															
Urine Analysis/wk															
Organism Visual Monitorings/wk															
Organism Recovery Preparation, No.															
Organism Live Recovery, No.															
Illumination, No./meas.															
Radiobiologies/wk															
Event Verification	10	20													
Histologies [9]	10	20													
Biochemistries [9]			20	20											
Substrate exchanges or subcultures/week	10	20													
Radiation Dosimetry	10	20													
POWER															OTHER
AC															
Continuous, watts	15	30	0	0											
Peak, watts															
Peak Duration, min/day															
DC															
Continuous, watts	10	20	0	0											
Peak, watts															
Peak Duration, min/day															
WEIGHT															
Organisms and Cages, kg (lb)	5 (11)	10 (22)	0.1 (0.22)	0.2 (0.44)											
Ancillary Research Equipment, kg (lb)	5 (11)	10 (22)	10 (22)	10 (22)											
VOLUME															
Organisms and Cages, m^3 (ft^3)	0.02 (0.7)	0.04 (1.4)	0.01 (0.35)	0.01 (0.35)											
Ancillary Research Equipment, m^3 (ft^3)	0.01 (0.35)	0.01 (0.35)	0.04 (1.4)	0.04 (1.4)											
LOGISTICS															
Weight at Launch, kg (lb)	11 (24)	21 (46)	11 (24)	22 (48)											
Supplies/Mo. Up, kg (lb)	1 (2.2)	1 (2.2)	0 0	0 0											
Supplies/Mo. Down, kg (lb)	0.8 (1.8)	0.8 (1.8)	0 0	0 0											
Weight at Termination, kg (lb)	10 (22)	20 (44)	11 (24)	22 (48)											
Volume at Launch, m^3 (ft^3)	0.03 (1.1)	0.05 (1.8)	0.05 (1.8)	0.05 (1.8)											
Supplies/Mo. Up, m^3 (ft^3)	0.01 (0.35)	0.01 (0.35)	0 0	0 0											
Supplies/Mo. Down, m^3 (ft^3)	0.01 (0.35)	0.01 (0.35)	0 0	0 0											
Volume at Termination															
Frozen Specimens Down	X	X													
Live Organisms Up	X	X													
Live Organisms Down	X	X													
Frozen Specimens Up															
Other															
COMMUNICATIONS															
Voice, hr/day	TBD	TBD	TBD	TBD	TBD	TBD									
TV, B&W, hr/day	X	X	X			X									
TV, Color, Ad Hoc	X	X	X	X	X	X									

preserved for immediate observation at experiment's end and others being cultured for continuing study.

Total package weight, volume, and envelope are:

Weight: 30 kg (66 lb)

Volume: 0.65 m^3 (23 ft^3)

Envelope: 91 × 91 × 76 cm (36 × 36 × 30 in)

4.4.2.1.3 Observation/Measurement Program. Observations (visual) will be made of the cell cultures at the end of the experiment. End-points taken will include a scoring of chromosome anomalies (breaks, fragments, exchanges, despiralization, anaphase, bridges, etc.), patterns of cell growth and nucleic acid synthesis, long-term cytogenetic effects, and activation of virus (three of the lines carry a low content of herpes-type virus). Eight temperature channels must be read out at least once every hour during flight.

4.4.2.1.4 Interface Support and Performance Requirements. General environment requirements are:

Temperature: 308 ±2°K (35 ± 2°C).

Relative Humidity: N/A.

Total Pressure: One Earth Atmosphere.

O_2N_2 Ratio: 20% - 80%.

Other Gases: Normal atmospheric.

Thermal Output: 10W continuous.

Unique environment requirements are:

Acceleration: Anything above 10^{-3} g undesirable.

Vibration: Minimal.

Rhythmic phenomena: N/A.

E-M phenomena: Earth normal.

Radiation: Onboard gamma radiation source required.

Power: 10 watts continuous at 26-32 Vdc.

Commands: Two, required to open and close radiation source.

Readout: Digital (temperature), 8 channels, once per hour for each.

Other: Command verification.

Crew support is minimal. If experiment is not automated, crew must open radiation source at beginning of experiment and close it at end of experiment. There are no other operations to be performed on board.

Prelaunch and launch requirements are provision of laboratory space and facilities, maintenance of environmental requirements, and hardware maintenance and preparation support.

Reentry and post-reentry requirements are to protect the experiment from environmental extremes and return hardware as soon as possible to experimenter.

4.4.2.1.5 Potential Role of Man. Due to the short-lived nature of this experiment, there is little need for manned participation other than that noted above. This kind of experimentation can be expanded, if desired, to utilize certain elements of the CORE and extensively utilize a technician-astronaut's time. Samples of cells can be withdrawn at intervals, observed and recultured over an extended mission. Cells could be subjected in orbit to 1-g and clinostat environments as further controls. The experiment has the potential of data gathering over a mission of an indefinite period, provided appropriate support is available.

4.4.2.2 Effects of Weightlessness on Molecular Reactions of Biological Interest. The principal objective of this experiment is to determine effects of weightlessness upon interactions large molecular aggregates in vitro (enzyme/substrate) simulating subcellular phase boundary conditions.

4.4.2.3 Effects of the Space Environment on the Rate of Mutation of Radiation-Resistant Microorganisms

4.4.3 ROLE OF GRAVITY IN INTERSPECIES RELATIONSHIPS. The experiment class objective is to discern the effect of removing the gravitational and other Earth-environmental factors on host-parasite relationships through use of cultured cells and a specific parasite (for example, a phage or parasitic microorganism). The experiment requirements summary is presented in Table 4-8.

4.4.3.1 Effects of Weightlessness on Plant Tumor Tissues. The basic objective of the experiment is to compare the responses of biological material in the space environment with material on and off clinostats on Earth to establish whether these

Table 4-8. Experiment Requirements Summary (Class: Role of Gravity in Interspecies Relationships)

EXPERIMENT NO. AND TITLE	4431 Effects of Weightlessness on Plant Tumor Tissues		4432 Effects of Space Environment on Insect Viruses and Virus Infected Insects		4433 Effect of Hypogravity on Host/Parasite Relationships in Bacteria										NOTES
SPECIMEN			Armyworms California Looper		Bacteria and Phage										
LOCATION	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	
NO. OF SPECIMENS															
HOLDING CAGES															[1] No periodic cues at whole-number fractions of 24 hours.
Standard	32**	64**	32***	64***	32#	64#									
Metabolic															
Colony															
MAN REQUIREMENTS, hr															[2] Normal Laboratory Max.: $\begin{cases} 10^{-3}g\ 90\%\ \text{of time} \\ 10^{-2}g\ 10\%\ \text{of time} \end{cases}$
Skill 1															
Setup															
Daily Average [3]															
Terminate															
Skill 2															[3] Ad Hoc observations required up to 8 hr/day. They cannot be scheduled and are part of the daily average. Crew time is average.
Setup	2	4	2	4	2	4									
Daily Average [3]	1	2	2	4	1	2									
Terminate	2	4	2	4	2	4									
Skill 4															[4] SMAC = Space maximum allowable concentration for man.
Setup															
Daily Average [3]															
Terminate															
EXPERIMENT DURATION, days	35	35	7-9	7-9	30	30									[5] No offensive or noxious odor.
ENVIRONMENTAL REQMTS															[6] TBD; minimal to reasonable engineering design effort.
pO_2, mm Hg	150±10	150±10	150±10	150±10	150±10	150±10									
pN_2 or Total Pressure, mm Hg	760±10	760±10	760±10	760±10	760±10	760±10									
pCO_2, mm Hg	<3	<3	< 3	< 3	<3	< 3									[7] Arterial & Venous
pCO, mm Hg	< 0.01	< 0.01													[8] Includes blood, feces, urine, bacterial, gas, and biopsy samples.
pNH_3, mm Hg	< 0.01	< 0.01													
pH_2O, mm Hg	26-28	26-28	16±2	16±2											
Temperature, °K (°C)	301±1 (28±1)	301±1 (28±1)	298±1 (25±1)	298±1 (25±1)	310±1 (37±1)	310±1 (37±1)									[9] Samples per week/ tests per sample
O_2 Consumption, kg/day	N	N	N	N	N	N									
CO_2, kg day	N	N	N	N	N	N									[10] Measurements made at holding unit level only; () = each organism.
Noise, dB	TBD	TBD	TBD	TBD	TBD	TBD									
Vibration, g (Hz)	TBD	TBD	TBD	TBD	TBD	TBD									
Acceleration, g			TBD	TBD	TBD	TBD									N = Negligible
Radiation, C/kg	[6]	[6]	[6]	[6]	[6]	[6]									
Illumination, lum/m^2 (ft-c)	0	0	970±50 (90±5)	970±50 (90±5)											*Carrot Daucus and Agrobacterium Tumerfaiens
Trace Contaminants															** dishes
NUMBER AND FREQUENCY OF MEASUREMENTS															*** dishes or test tubes
															# test tubes

Table 4-8. Experiment Requirements Summary (Class: Role of Gravity in Interspecies Relationships), Contd

EXPERIMENT NO.	4431		4432		4433										NOTES
LOCATION	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	
NUMBER AND FREQUENCY OF MEASUREMENTS															
Samples [8] Prep for Earth Return/wk															
pO_2, hourly															
pCO_2, hourly [10]															
pNH_3, hourly [10]															
pH_2O, hourly [10]															
Temp., hourly [10]	1	2	1	2	1	2									
Noise, continuous [10]	1	2													
Vibration, cont. [10]	1	2	1	2	1	2									
Acceleration, cont. [10]	1	2	1	2	1	2									
Radiation, cont. [10]	1	2	1	2	1	2									
Organism Sacrifice/wk															
Urine Analysis/wk															
Organism Visual Monitorings/wk															
Organism Recovery Preparation, No.															
Organism Live Recovery, No.															
Illumination, No./meas.															
Radiobiologies/wk															
Photography Pictures/Day	32	64													
Substrate Exchanges or Subcultures/wk.	32	64													
Specimen Size msmts/Wk	64	128													
Sample Preservation per Expt.	32	64													
Bacterial Samples					32	64									
Bacterial Assay					32	64									
POWER															OTHER
AC															
Continuous, watts	5	10	10	20	5	10									
Peak, watts															
Peak Duration, min/day															
DC															
Continuous, watts	5	10	4	8	2	4									
Peak, watts															
Peak Duration, min/day															
WEIGHT															
Organisms and Cages, kg (lb)	2(4.4)	4(8.8)	2(4.4)	4(8.8)	2(4.4)	4(8.8)									
Ancillary Research Equipment, kg (lb)	8(18)	16(35)	10(22)	12(26)	10(22)	12(26)									
VOLUME															
Organisms and Cages, m^3 (ft^3)	0.02 (0.7)	0.04 (1.4)	0.02 (0.7)	0.04 (1.4)	0.02 (0.7)	0.04 (1.4)									
Ancillary Research Equipment, m^3 (ft^3)	0.08 (2.8)	0.10 (3.5)	0.04 (1.4)	0.05 (1.8)	0.04 (1.4)	0.05 (1.8)									
LOGISTICS															
Weight at Launch, kg (lb)	12(26)	22(48)	13(29)	17(37)	13(29)	17(37)									
Supplies/Mo. Up, kg (lb)	2(4.4)	2(4.4)	1(2.2)	1(2.2)	1(2.2)	1(2.2)									
Supplies/Mo. Down, kg (lb)	1.6 (3.5)	1.6 (3.5)	0.8 (1.8)	0.8 (1.8)	0.8 (1.8)	0.8 (1.8)									
Weight at Termination, kg (lb)	12(26)	22(48)	12(26)	16(35)	12(26)	16(35)									
Volume at Launch, m^3 (ft^3)	0.1 (3.5)	0.14 (5)	0.06 (2)	0.09 (3)	0.06 (2)	0.06 (2)									
Supplies/Mo. Up, m^3 (ft^3)	0.01 (0.35)	0.01 (0.35)	0.01 (0.35)	0.01 (0.35)	0.01 (0.35)	0.01 (0.35)									
Supplies/Mo. Down, m^3 (ft^3)	0.01 (0.35)	0.01 (0.35)	0.01 (0.35)	0.01 (0.35)	0.01 (0.35)	0.01 (0.35)									
Volume at Termination															
Frozen Specimens Down	X	X													
Live Organisms Up	X	X	X	X	X	X									
Live Organisms Down			X	X	X	X									
Frozen Specimens Up															
Other															
COMMUNICATIONS															
Voice, hr/day	TBD	TBD	TBD	TBD	TBD	TBD									
TV, B&W, hr/day															
TV, Color, Ad Hoc	X	X	X	X	X	X									

responses are similar in all respects. Thus, comparisons can be made of the following gravity-dependent responses:

a. Size of tumors reflecting increased metabolic activity hypothesized to occur in weightlessness.

b. Polar responses hypothesized to result in greater tumor formation on basal facing surfaces.

c. Pathological responses reflected in tumor development.

d. Changes in patterns of cell division, cell wall formation, and cell size hypothesized to occur under conditions of weightlessness.

4.4.3.1.2 Description. The basic experimental design consists of two discs of carrot tissue. One disc is inverted while the other disc is left in its original position. The upper surface of each carrot disc is inoculated with Agrobacterium tumerfaciens. The inoculated discs, along with similar uninoculated material, will then by subjected to:

a. Weightlessness in the space environment.

b. Conditions of 1g with onboard centrifuge.

c. Ground control, 1g.

d. Ground control, clinostat.

e. Ground control, backup.

Inoculated and uninoculated material will be killed and fixed at 7, 14, 21 and 28 days after launch for the determination of tumor weights, anatomical and cytological studies, and enzyme studies.

Total package weight, volume and envelope is:

Weight	5 kg (11 lb)
Volume	0.02 m^3 (1000 $in.^3$)
Envelope	22x23x33 cm (8 1/2x9x13 in)

The above capability would account for a "set" of carrot discs, the number depending upon size of sample needed for a valid statistical measure.

In addition to onboard centrifuge capability, availability of a clinostat to serve as an orbiting control for the clinostat sample on the ground may be desirable. This could be a component of common-use equipment.

4.4.3.1.3 Observation/Measurement Program. The different sets of inoculated and uninoculated material will be killed and fixed at 7, 14, 21 and 28 days after launch for the determination of tumor weights, anatomical and cytological studies, polar responses, changes in patterns of cell division cell wall formation and size. Four temperature channels must be read out at least every 20 minutes. Actuations occurring must be verified in real-time or near-real-time.

4.4.3.1.4 Interface Support and Performance Requirements. General environment requirements are:

Temperature: 301 ± 1°K (28 ± 1°C)

Relative Humidity: 70% ± 10%

Total Pressure: One Earth atmosphere.

O_2N_2 Ratio: 20%-80%

Other Gases - Normal Atmospheric Thermal Output: TBD.

Unique environment requirements are:

Acceleration: Anything above 10^{-4} g undesirable; 10^{-3} g can be tolerated 5% of time.

Vibration: Minimal.

Rhythmic phenomena: N/A.

E-M phenomena: Earth normal.

Power required is to be determined.

Data management requirements are:

Command: 1/wk. for 4 weeks.

Readout, Digital: Temperature, 4 channels, 1 per orbit (measurements every 20 min.)

Other: Verifications of commands.

Based on the above information for automated and returned experiment, crew support is minimal, requiring only the three fixation actuations (occurring three times through a 28-day mission). Based on maximal manned support, assuming manual treatments and observations, the following may apply:

Experiment setup: 6 hours (1/28 days).

Research activities: Photography, 30 minutes per event; 1 event/3 days for 28 days.

Visual observations: 1 hour per event; 1 event/3 days for 28 days.

Experiment termination (shutdown, logistics, loading and/or equipment refurbishment): 2 hr/event; 1 event/mission.

Skill level: Highly trained technician or professional plant physiologist.

Orbital Altitude and Inclination: N/A. Prelaunch and launch requirements are provision of laboratory space and facilities, maintenance of environmental requirements, and hardware maintenance and preparation support.

Reentry and post-reentry requirements are the same as for launch and prelaunch; automated package returned to investigator within 8 hours of reentry.

4.4.3.1.5 Potential Role of Man. This experiment would benefit considerably by the direct involvement of man in its implementation. A greater number of sample specimens could be studied; the specimens could be treated in a variety of ways to prepare them for specific cytological and histochemical analyses; observations could be made serially to define a time course of events; experimental adjustments could be more readily made. Such an astronaut would have to be highly trained in this discipline, of course, for results to be accepted as valid.

The duties of a scientist-astronaut may include the following:

a. Soon after insertion into orbit, 540 carrot discs are cut. Of these, 270 are inverted from their original positions relative to apical and basal ends of the carrot. All are then inoculated with the crown gall tumor bacteria on the upper surface.

b. These are then apportioned over the three experimental variables: weightlessness, centrifuge (1g) and 3 π clinostat. The sample size for each interval of exposure will be ten. Thus, at each interval (3, 7, 10, 14, 17, 21, 24 and 28 days) twenty discs will be removed from each condition, 10 of which were inverted before inoculation. This will leave twenty for continued exposure or to be returned unfixed.

c. Upon removal for observation and fixation, at each interval, carrot discs will be photographed and observations recorded. Further treatment may include the application of cytochemical staining procedures, freezing for more intensive chemical analysis, weighing or mass determination, etc.

d. Based upon observations, the intervals may be lengthened or shortened to optimize experimental design. Data will be coordinated with concurrent ground controls, and decisions made in consideration of all variables.

e. At conclusion of mission, specimens will be prepared for return in transport containers.

4.4.3.1.6 Available Background Data. A proposal from a principal investigator has been received and reviewed by NASA as a submission to the Experiment Survey Program of AIBS. From this, ARC has summarized an Experiment Data Sheet. In addition, there is considerable literature concerned with root polarity.

4.4.3.2 Effect of Space Environment on Insect Viruses and Virus-Infected Insects. The scientific objectives of this experiment are:

a. To determine if insect viruses will mutate, or lose infectivity from ionizing radiation of space.

b. To determine susceptibility of insects to viruses in space.

c. To determine behavior of virus-infected insects in space. Virus infected larva will be exposed to space flight; the behavior of the infected larvae in space will be monitored with a movie camera.

Similarly, viruses in smears and suspensions will be exposed. After flight these viruses will be subject to bioassay for mutations, infectivity and pathogenicity.

Organism (Hosts): Armyworm, Beet Army Worm, California looper.

4.4.3.3 Effect of Hypogravity on Host/Parasite Relationships in Bacteria. This experiment's scientific objective is to detect the effect of weightlessness upon the course of parasitism by a virus or parasitic bacterium on a host bacterium.

Organism: Bacteria/Phase system.

4.5 FPE INTERFACE, SUPPORT AND PERFORMANCE REQUIREMENTS

The summary data presented in Table 4-9 represents, in the best judgment of NASA scientists, the overall facility and experimental requirements to accomplish a realistic experimental program, and is based on some projection of the state-of-the-art. The rationale for selection of the summary parameters is in some instances arbitrary but has as a basis the total NASA experience and knowledge gained from prior flight and experiment definition and integration programs. The basis for each data entry is given in the notes.

4.6 POTENTIAL MODE OF OPERATION

The recommended mode of operation is within a common-use bioresearch laboratory. The cells and tissue research facility is required to heavily support other FPEs in microbiological monitoring and support. If the gravity requirements (10^{-5} 95% of the time and 10^{-4} 10% of the time) cannot be met by the support vehicle and

Table 4-9. Cells and Tissue Research Facility FPE Summary Data

Weight, kg (lb)	2081 (4600)	Note 1
Volume, m^3 (ft^3)	14.3 (515)	Note 1
Power, watts	3310	Note 2
Crew Skills		
1. Biological Technician		
2. Microbiological Technician		
3. Biochemist		
12. Electromechanical Technician		
Data Rate, bps	353	Note 2
Analog Data: hours/day	1.8	
frequency, MHz	4	
Logistics Up, 30-day average, kg (lb)	27 (60)	Note 3
Logistics Down, 30-day average, kg (lb)		
1st 2 years	20 (44)	Note 4
3rd year on	24 (53)	Note 5
Pointing and Stabilization	NA	
Orbit Altitude and Inclination	NA	
Unique Environment Requirements	Isolation from rhythmic phenomena, noise, vibration, and possibly from EMI and ESI. Acceleration allowable at holding unit < 10^{-5}g.	

NOTES:

1: CORE units + FPE units + two logistic cycles of expendables + 1 complement of test subjects. Radiobiology unit and bioresearch centrifuge not included.
2: 40% of CORE units total + 75% of FPE units total = normal load.
3: 1% of FPE units + 80% of expendables to support total specimen holding capability + 16 2/3% specimen complement (equivalent to 50% replacement of specimens every 90 days).
4: 75% of logistics up.
5: 90% of logistics up.

laboratory, then a soft-mounting system for the holding units must be developed. If the soft-mounting system cannot provide the gravity requirements, a fly-away module may be considered; however, the docking environment and the impact of inaccessibility must be evaluated.

With regard to the specific Mode A, limited on-orbit stay time as with Space Shuttle, there are some experiments of less than 30 days duration which can be accommodated but there are other experiments which require more than 30 days and cannot be accommodated. As for Mode B, extended on-orbit stay time, unmanned, with periodic revisits by Space Shuttle, there are some experiments which can be automated for accommodation by this mode, but the interval between crew visits should not exceed 30 days and a shorter interval such as 15 days is much preferred. Some experiments require Mode C, extended on-orbit stay time with Space Station, and this is the preferred mode for all experiments of this FPE.

4.7 ROLE OF MAN

Based on all activities in all experiments, man may potentially carry out the functions itemized below. In a high-load day in which contingencies call for the absolute maximum effort, the scientist may be required to devote 14 or more hours to experiment manipulations. These occasions will be infrequent, occurring mainly at experiment setup and termination times. In contrast with a fixed load on a minimum-effort day, considering only housekeeping and colony management, the scientist may be committed to as little as two hours' time, leaving him free for creative activities such as onboard data reduction and interpretation and planning of new and follow-on experiments. The average day, including housekeeping plus ad hoc research activities, will be 6 to 8 hours long.

a. Routine tasks (all experiments):

 1. Laboratory housekeeping, maintenance and repair
 2. Experiment setup
 3. Monitor organisms, hardware and data
 4. Experiment termination
 5. Specimen preparation for logistics return; package experiments, samples, photographs and other records for return to earth.

b. Experiment-peculiar research activities (desirable to enhance scientific value and responsiveness of experiment, but not critical to successful execution of basic experiment):

 1. Set up follow-on experiments with tissue from prior experiments, onboard organisms, and/or newly arrived organisms.
 2. Common lab techniques, e.g., mass measurement, fluid handling.

3. Perform laboratory analysis (biochemistries).

4. Gross morphological examination.

5. Cytological and histological preparations and preliminary analysis.

6. Programmed and ad hoc photography at request of P.I.

7. Ad hoc TV monitoring in conference with P.I.

8. Install and operate plate physiological and metabolic instrumentation, etc.

9. Radiobiology techniques (isotopic tracers): administer and detect.

10. Collect and preserve whole specimens.

11. Dissect and freeze specimens with dry ice or LN_2.

4.8 SCHEDULES

Experiment development time, in years required for flight readiness, is shown in Table 4-10.

4.9 PRELAUNCH SUPPORT AND GSE

A common-use Life Sciences Laboratory is required at the launch area to support the experiment packages and, in most cases, maintain sterility. It is suggested that this facility be sufficiently comprehensive to allow all the Principal Investigators and their research team to do all final assemblies and preparations.

A Life Sciences general ground control facility is required to provide a delayed simulation of the space bioresearch lab in terms of radiation, vibration, atmospheric composition, and man involvement. An optimum design is a duplicate facility of the space bioresearch lab, supported by the necessary radiation sources, mechanical actuation and bottle gas inventory, operated on the ground for all biological control. Separation of the FPEs in the control facility can introduce additional variables.

The launch preparation facility and the ground control facility should be in the same complex. Direct link to mission control would provide communication with the space lab and the control facility and members of the experiment research staff.

4.10 SAFETY ANALYSIS

Safety hazards and precautions are listed in Table 4-11.

Table 4-10. Development Schedule

	1	2	3	4	5	6	YEARS
4.4.1.1 The Role of Gravity in Life Processes (Microorganisms, Cells and Tissues)	—						
4.4.1.2 Effect of Weightlessness, Space Vacuum and Radiation on Soil Sample Integration and Viability during Long Term Storage and Preservation	———	———	———	———	———		
4.4.1.3 Effects of Weightlessness on Morphogenesis and Embryogenesis in Cultured Somatic Cells	———	———					
4.4.1.4 Effects of Weightlessness on the Morphology, Histology, and Biochemistry of Bone Tissue Cultures	———	———	———	———	———		
4.4.1.5 The Effects of the Space Environment on Periodicity of Growth and Conidial Formation in Fungi	———	———					
4.4.1.6 The Effect of Weightlessness on Functional and Developmental Stability of Vertebrate Embryos	———	———	———				
4.4.1.7 Effects of Weightlessness and Hormones on Bone Culture Mineral Metabolism	———	———	———	———	———		
4.4.1.8 Effects of Weightlessness on the Calcium Metabolism of Human Cells in Tissue Culture	———	———					
4.4.2.1 Effects of Weightlessness on Chromosomes and Nucleic Synthesis of Human Tissue Cultures	———	———	———				
4.4.2.2 Effects of Weightlessness on Molecular Reactions of Biological Interest	———						
4.4.2.3 Effect of the Space Environment on the Rate of Mutation of Radiation Resistant Microorganisms	———						

Table 4-10. Development Schedule, Contd

	1	2	3	4	5	6	YEARS
4.4.3.1 Effects of Weightlessness on Plant Tumor Tissues	———						
4.4.3.2 Effect of Space Environment on Insect Viruses and Virus-infected Insects	———————						
4.4.3.3 Effect of Hypogravity on Host/ Parasite Relationships in Bacteria	———————						

Table 4-11. Safety Analysis

Hazards	Precautions
1. Incubator Atmosphere	Case-open operation in hooded workbench. Slight Δ P into incubator.
2. Overpressurization of incubator	Pressure relief valve.
Experiment Procedures 1. Microorganism Manipulations	Work in hooded area. Use syringe transfer when possible. Use closed induction heat element for transfer loop, needle sterilization, and slide drying.
2. Chemical Exposure (Including Stains)	Work in hooded area. Purge capability. Store in unbreakable containers. Store in hermetically sealed cabinet which is purgable. Emergency life support.

4.11 AVAILABLE BACKGROUND DATA

Bioscience Experiment Opportunity Survey Questionnaires.

Proprietary Proposals Received by NASA.

VOLUME VIII

SECTION 5

INVERTEBRATE RESEARCH FACILITY

SECTION 5

INVERTEBRATE RESEARCH FACILITY

5.1 GOALS AND OBJECTIVES

This FPE is to define the laboratory support and operational requirements for an invertebrate research facility which, with the CORE, will permit a broad spectrum of specific and general experimentation in pursuit of the goals and objectives discussed under the Space Biology portion of the Life Sciences Introduction. Such a facility provides holding and rearing accommodations as well as research instrumentation for a wide variety of invertebrates. The rearing accommocations will permit establishing a "weightlessness adapted" strain of selected invertebrates considered essential in studying adaptive processes. It is of interest to:

a. Assess the effects of exposure to the spectrum of ionizing radiation that may be encountered in space flight.

b. Quantify the effects in relation to energy, dose and dose rate as well as to other space flight variables, e.g., weightlessness.

c. Apply the quantitative information to problems of radiation therapy.

d. Answer questions on the potential hazard of space radiation to extended manned missions such as planetary exploration.

Initial emphasis will be placed on studies involving early adaptive processes, nutritional and water balance, and genetics as they may relate to practical problems in manned flight. These studies will also serve to indicate the most important areas for follow-on or in-depth investigation.

5.2 PHYSICAL DESCRIPTION

This facility will include invertebrate holding and rearing elements, in addition to appropriate parts of the Research Centrifuge, Radiobiology Unit, Specimen Return Unit, and CORE shared with the Medical Research Facility and other Life Sciences FPEs. The facility concept is illustrated in Figure 5-1.

The holding facilities should provide 0.5 m^3 (18 ft^3) of incubator space at three environmental conditions within the main biology laboratory. If a centrifuge is or becomes available, an additional holding facility of equal space and environmental capability will be provided onboard the centrifuge. The holding units on the centrifuge will be at different levels, i.e., 0.1, 0.5, 1.0 g.

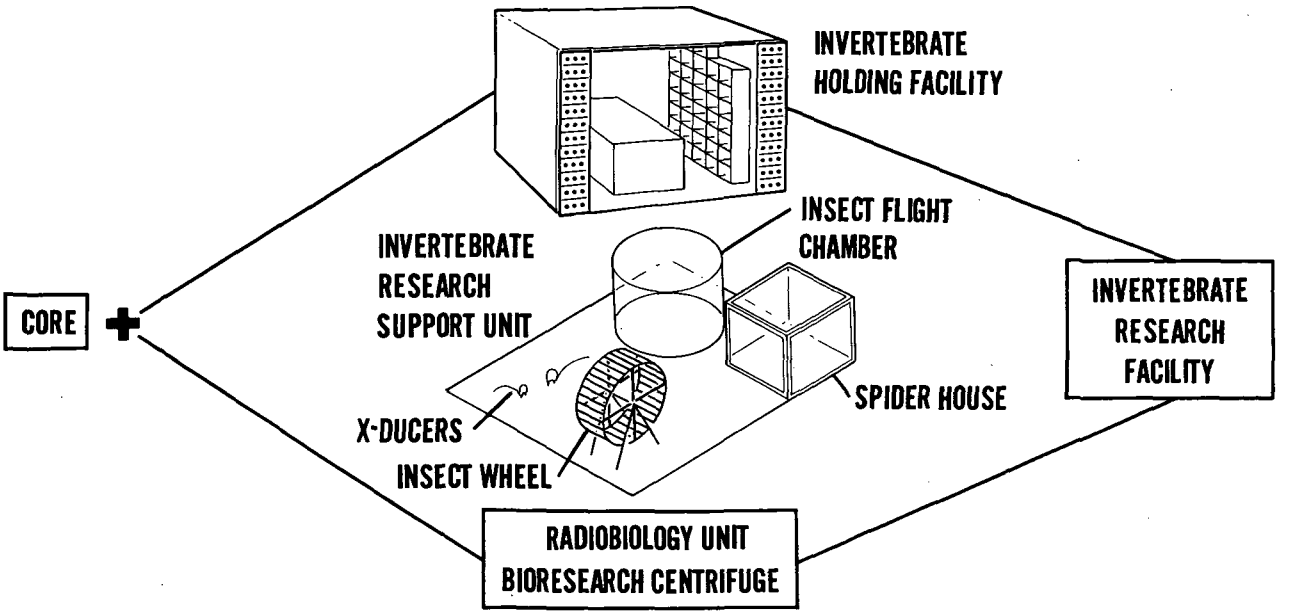


Figure 5-1. Life Sciences Invertebrate Research Facility

As discussed in the Life Sciences introduction, these facilities are not "all or none" and a certain lesser capability is acceptable for selected experiments. It is anticipated that certain missions will, in fact, be limited in the amount and scope of experimental payloads as well as in crew size and flight time. Therefore, scheduling and operational planning will necessarily be dependent upon available technology, mission parameters, and the urgency for specific information.

5.2.1 INVERTEBRATE HOLDING UNIT

5.2.1.1 Functional Capability. To house invertebrate specimens and support experimental equipment required for invertebrate research.

5.2.1.2 Description. The housing or enclosures consist of a rack assembly which will hold the experiment package and a plug-in system to the packages to supply the different support systems. Each package will slide into position and be mechanically secured in place. The auxiliary support system can then be connected by way of quick-disconnect-type connectors. Packages should be quickly and easily removed without interfering with or interception of the other packages.

Packages should be grouped by temperature groups; several packages could be together in one section if they need one particular temperature. Some packages will require several different temperature settings during a space flight, and thus need

a section for each package. Each section will require its own temperature control system (heating or cooling) which can hold the desired temperature to a close tolerance (e.g., ± 1° K). This control should be capable of adjustment by the crew over a range of 283 to 333° K (10-60° C).

The enclosure should be sealed to maintain an ambient pressure of one Earth atmosphere, which is required by all of the insect experiments. There should be a pressure release valve to prevent overpressurization of the enclosure. If the spacecraft is at a lower ambient pressure than one atmosphere and it is necessary to open the enclosure to this lower pressure, the packages will have to be sealed and pressurized in order to maintain an experiment package ambient pressure of one atmosphere. There should also be a release valve in each package.

It may be desirable to actuate the experiment commands by manual means (knobs, pull rods, etc.) by the crew. The package in this case would be the simplest, both mechanically and electrically. However, the openings for shafts, etc., will have to be sealed when a differential pressure exists between the package and enclosure or spacecraft.

Other environmental requirements are:

	Range	Typical Requirement
Relative Humidity	20-90%	50 ± 20%
pO_2	100-200 mm Hg	150 ± 5 mm Hg
pN_2	550-650 mm Hg	600 ± 10 mm Hg
pCO_2	0-5 mm Hg	1 ± 1 mm Hg
Lighting	0-1300 lum/m^2 (0-120 ft-c)	1000 ± 100 lum/m^2 (93 ± 10 ft-c)

Unique environment requirements are:

Acceleration:	10^{-5}g or less, 95% of the time; 10^{-3}g or less, 5% of the time.
Vibration:	TBD (minimum)
Rhythmic phenomena:	Minimum allowable.
E-M phenomena:	Earth normal.

Table 5-1 is an equipment-unit summary for the Invertebrate Holding Unit.

Table 5-1. Equipment Unit Summary

	Laboratory Only	Laboratory + Centrifuge
OPERATOR SKILL	1	1
POWER, AC		
average, watts	150	150
peak, watts	150	150
peak duration, hr/day	24	24
POWER, DC		
average, watts	300	300
peak, watts	300	300
peak duration, hr/day	24	24
WEIGHT, kg (lb)	100(220)	180(400)
ENVELOPE		
volume, m^3 (ft^3)	0.6(21)	1.2(42)
height, cm (in.)	TBD	TBD
width or diam. cm (in.)	TBD	TBD
depth, cm (in.)	TBD	TBD
DATA		
voice, hr/day	TBD	TBD
TV, B&W, hr/day		
TV, color, hr/day		
analog, MHz	4(1 hr/day)	4(2 hr/day)
digital, bps	310	620

5.2.2 INVERTEBRATE RESEARCH SUPPORT UNIT

5.2.2.1 Functional Capability. This equipment unit contains all the specific tools, containers, and transducers required for invertebrate research. All experiment-peculiar hardware brought up for invertebrate studies and which remains in the lab becomes part of this equipment unit. The capabilities are:

a. Camera optics specific for invertebrates.

b. Special holding cages (flies, bees, cockroaches, etc.).

c. Microrespirometers.

d. Flight Chambers.

e. Invertebrate Transducers.

f. Eclosion Rate Monitoring.

5.2.2.2 Description. This equipment unit is basically a system of drawers, cabinets, and specific rack storage as listed in Table 5-2. Table 5-3 is an equipment-unit summary.

5.3 *EXPERIMENT REQUIREMENTS SUMMARY*

Experiment requirements are summarized in Tables 5-5, 5-6, and 5-7.

5.4 EXPERIMENT PROGRAM

The invertebrate research program is comprised of a group of representative experiment classes, each supported by a group of representative experiments. Within each

Table 5-2. Invertebrate Research Support Unit Equipment List

Name	Performance Characteristics	Power W	Weight kg (lb)	Volume m^3 (ft^3)
Rack and Cabinet System	Racks, cabinets, or drawers containing present invertebrate hardware and all future hardware for invertebrate research.	0	25 (55)	0.5 (17.5)
Vials, Bottles, Honeycombs, etc.	Individual and colony caging units.	0	15 (33)	0.3 (10)
Miscellaneous Counters and Transducers		0	5 (11)	0.1 (3.5)
Specific Tools and Zero-g Aid for Invertebrate Biology		0	5 (11)	0.1 (3.5)

Table 5-3. Equipment Unit Summary

	Laboratory Only	Laboratory + Centrifuge
OPERATOR SKILL	TBD	TBD
POWER, AC		
average, watts	0	0
peak, watts	0	0
peak duration, hr/day	0	0
POWER, DC		
average, watts	0	0
peak, watts	0	0
peak duration, hr/day	0	0
WEIGHT, kg (lb)	45(100)	55(210)
ENVELOPE		
volume, m^3 (ft^3)	0.5(17.5)	0.75(26)
height, cm (in.)	TBD	TBD
width or diam. cm (in.)	TBD	TBD
depth, cm (in.)	TBD	TBD

class, the first representative experiment is described in detail; other representative experiments are given by title and experiment requirements data only. These selected representative experiments provide experiment support requirements and other spacecraft and mission impacts to a level ample to characterize the requisite Invertebrate Research Facility. Table 5-4 enumerates the representative experiment classes and representative experiments that scope the experiment program.

5.4.1 ROLE OF GRAVITY IN INVERTEBRATE LIFE PROCESSES. The scientific objective of this experiment class is to detect, quantify and determine the mechanisms of alterations in the basic life processes of invertebrates exposed to weightlessness. These life processes will include, but not be limited to:

Reproduction
Embryology
Morphogenesis
Intermediary Metabolism
Neuromuscular Function
Hormone Function

Growth	Biorhythms
Development	Regeneration and Tissue Repair
Maturation	Aging and Longevity
Nutrition	Interspecies Relationships

A wide variety of biochemical, physiological, and biophysical methodologies will be available for accomplishment of the work. The experiment requirements summary for the class is presented in Table 5-5.

Table 5-4. Invertebrate Research Facility

Section	Title
5.4.1	Experiment Class: Role of Gravity in Invertebrate Life Processes
5.4.1.1	Experiment: Longevity and behavioral changes (in vinegar gnats) in space
5.4.1.2	Experiment: Space-flight effects of aging and longevity
5.4.1.3	Experiment: Effect of weightlessness on regeneration of planaria
5.4.2	Experiment Class: Effect of Space Environment on Invertebrate Behavior
5.4.2.1	Experiment: Circadian periodicity of cockroach activity and respiration
5.4.2.2	Experiment: Circadian rhythm of vinegar gnat eclosion
5.4.2.3	Experiment: Effect of weightlessness on web-building behavior of spiders
5.4.3	Experiment Class: Effect of Space Environment on Invertebrate Genetics
5.4.3.1	Experiment: Combined space and irradiation effects
5.4.3.2	Experiment: Effects of space environment on genetic changes
5.4.3.3	Experiment: Genetic effects of space flight on sperm and ovum
5.4.3.4	Experiment: Chromosome rejoining at zero-g

Table 5-5. Experiment Requirements Summary (Class: Role of Gravity in Invertebrate Life Processes)

EXPERIMENT NO. AND TITLE	5411 Longevity and Behavioral Changes (In Vinegar Gnats) in Space		5412 Space Flight Effects of Aging and Longevity		5413 Effect of Weightlessness on Regeneration of Planaria										NOTES
SPECIMEN	Vinegar Gnat		House Fly		Planaria										
LOCATION	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	
NO. OF SPECIMENS [11]	1000	2000	2000	2000	10	20									
HOLDING CAGES															[1] No periodic cues at whole-number fractions of 24 hours.
Standard															
Metabolic															
Colony	5	10	60	120											
MAN REQUIREMENTS, hr															[2] Normal Laboratory
Skill [1]															
Setup	8	16	4	8	0.5	1									Max.: 10^{-4}g 95% of time; 10^{-3}g 5% of time
Daily Average [3]	0.5	1	0.2	0.4	2	4									
Terminate	4	8	1	1	1	2									[3] Ad Hoc observations required up to 8 hr/day. They cannot be scheduled and are part of the daily average. Crew time is average.
Skill [3]															
Setup															
Daily Average [3]															
Terminate															
Skill [4]															[4] SMAC = Space maximum allowable concentration for man.
Setup															
Daily Average [3]															
Terminate															
EXPERIMENT DURATION, days	90	90	3-2/3 [12]	3-2/3 [12]	45	45									[5] No offensive or noxious odor.
ENVIRONMENTAL REQMTS															[6] TBD; minimal to reasonable engineering design effort.
pO_2, mm Hg	150±10	150±10	150±10	150±10	150±10	150±10									
Total Pressure, mm Hg	760±10	760±10	760±10	760±10	760±10	760±10									[7] Arterial & Venous
pCO_2, mm Hg	<3	<3	<3	<3	<3	<3									
pCO, mm Hg	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01									[8] Includes blood, feces, urine, bacterial, gas, and biopsy samples.
pNH_3, mm Hg															
pH_2O, mm Hg	6-15	6-15	9-17	9-17											
Temperature, °K (°C)	(23±1) 296±1	(23±1) 296±1	*	*	(37±1) 310±1	(37±1) 310±1									[9] Samples per week/ tests per sample
O_2 Consumption, kg day	Negl	Negl	Negl	Negl	Negl	Negl									
CO_2, kg day	Negl	Negl	Negl	Negl	Negl	Negl									[10] Measurements made at holding unit level only; () = each organism.
Noise, dB	[1] [6]	[1] [6]	[1] [6]	[1] [6]	[1] [6]	[1] [6]									
Vibration, g (Hz)	[1] [6]	[1] [6]	[1] [6]	[1] [6]	[1] [6]	[1] [6]									[11] Plus progeny.
Acceleration, g	[2]	0.5, 1.0	[2]	TBD	[2]	1.0									
Radiation, C/kg	**	**	**	**	[6]	[6]									[12] Must be returned to lab in 88 hr.
Illumination, lum/m^2 (ft-c)	(100±10) 1080±100	(100±10) 1080±100	0	0	(90±10) 970±100	(90±10) 970±100									
Trace Contaminants	[4]														
NUMBER AND FREQUENCY OF MEASUREMENTS															*(26.5±0.5) 299.5±0.5
															**Normal Earth

Table 5-5. Experiment Requirements Summary (Class: Role of Gravity in Invertebrate Life Processes), Contd

EXPERIMENT NO.	5411		5412		5413										NOTES
LOCATION	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	
NUMBER AND FREQUENCY OF MEASUREMENTS															
Samples [8] Prep for Earth Return/wk															
pO_2, hourly	(6)	(6)	(6)	(6)	(6)	(6)									
pCO_2, hourly [10]	(6)	(6)	(6)	(6)	(6)	(6)									
pNH_3, hourly [10]															
pH_2O, hourly [10]	(6)	(6)	(6)	(6)	(6)	(6)									
Temp., hourly [10]	(6)	(6)	(6)	(6)	(6)	(6)									
Noise, continuous [10]	(6)	(6)	(6)	(6)	(6)	(6)									
Vibration, cont. [10]	(6)	(6)	(6)	(6)	(6)	(6)									
Acceleration, cont. [10]	(6)	(6)	(6)	(6)	(6)	(6)									
Radiation, cont. [10]	(6)	(6)	(6)	(6)	(6)	(6)									
Organism Sacrifice/wk															
Urine Analysis/wk															
Organism Visual Monitorings/wk															
Organism Recovery Preparation, No.															
Organism Live Recovery, No.															
Illumination, No./meas.															
Radiobiologies/wk															
Crew Observations/day	4	4	2	2	0.5	0.5									
Activity, continuous															
Organism Preservation	X	X													
Organism-Earth Return	X	X	X	X											
Oviposition Observations per day	4	4													
Status - Alive-Moribund/Dead Obs/day	4	4													
Event Start/Stop	X	X	X	X	X	X									
Photomicrographs					100	200									
POWER															OTHER
AC															
Continuous, watts	10	20	10	20	10	20									
Peak, watts															
Peak Duration, min/day															
DC															
Continuous, watts	2	4	2	4	2	4									
Peak, watts															
Peak Duration, min/day															
WEIGHT															
Organisms and Cages, kg (lb)	5.6 (12)	11.2 (25)	10 (22)	20 (44)	12 (26)	24 (53)									
Ancillary Research Equipment, kg (lb)	2 (4.4)	2 (4.4)	3 (6.6)	4 (8.8)	2 (4.4)	3 (6.6)									
VOLUME															
Organisms and Cages, m^3 (ft^3)	0.024 (0.85)	0.048 (1.69)	0.04 (1.4)	0.08 (2.8)	0.028 (1)	0.056 (2)									
Ancillary Research Equipment, m^3 (ft^3)	0.03 (1.0)	0.06 (2.1)	0.01 (0.35)	0.02 (2.12)	0.01 (0.35)	0.02 (0.71)									
LOGISTICS															
Weight at Launch, kg (lb)	8.5 (18.7)	15 (33)	15 (33)	28 (61.6)	15 (33)	29 (63.8)									
Supplies/Mo. Up, kg (lb)	1 (2.2)	2 (4.4)	2 (4.4)	4 (8.8)	1 (2.2)	2 (4.4)									
Supplies/Mo. Down, kg (lb)	0.8 (1.8)	1.6 (3.5)	1.6 (3.5)	3.2 (7)	0.8 (1.8)	1.6 (3.5)									
Weight at Termination, kg (lb)	8 (17.6)	15 (33)	15 (33)	28 (61.6)	15 (33)	29 (63.8)									
Volume at Launch, m^3 (ft^3)	0.06 (2.1)	0.1 (3.5)	0.05 (1.8)	0.1 (3.5)	0.04 (1.4)	0.08 (2.8)									
Supplies/Mo. Up, m^3 (ft^3)	0.01 (0.35)	0.01 (0.35)	0.01 (0.35)	0.01 (0.35)	0.01 (0.35)	0.01 (0.35)									
Supplies/Mo. Down, m^3 (ft^3)	0.01 (0.35)	0.01 (0.35)	0.01 (0.35)	0.01 (0.35)	0.01 (0.35)	0.01 (0.35)									
Volume at Termination	0.06 (2.1)	0.1 (3.5)	0.05 (1.8)	0.1 (3.5)	0.04 (1.4)	0.08 (2.8)									
Frozen Specimens Down															
Live Organisms Up	X	X	X	X	X	X									
Live Organisms Down	X	X	X	X	X	X									
Frozen Specimens Up															
Other Film	X	X	TBD	TBD											
COMMUNICATIONS															
Voice, hr/day	TBD	TBD	TBD	TBD	TBD	TBD									
TV, B&W, hr/day	X	X	X	X	X	X									
TV, Color, Ad Hoc	X	X	X	X	X	X									

5.4.1.1 Longevity and Behavioral Changes (in Vinegar Gnats) in Space

5.4.1.1.1 Scientific Objectives. Experiment objectives are:

a. To investigate the effects of the space environment on longevity, behavior, and histological and biochemical characteristics of the vinegar gnat.

b. To investigate the mating behavior, fertility, and embryonic development of the vinegar gnat.

5.4.1.1.2 Description. To investigate the longevity, behavior, histological and biochemical characteristics of adults, four packages, each containing 250 adult gnats, isolated in individual "cells" on an agar-molasses base, will be flown simultaneously for 90 days. The population of 1000 is broken into four groups to permit comparison of replicates and to avoid loss of the total experiment due to single package failure. Package parameters are:

	Each Package	Total (4)
Weight:	0.7 kg (1.5 lb)	2.8 kg (6 lb)
Volume:	0.03 m^3 (1 ft^3)	0.12 m^3 (4 ft^3)
Envelope:	TBD	TBD

To investigate mating behavior, fertility and development, simple experiments on embryology, juvenile development, and the newly emerged adult will be accomplished in four packages each containing 500 fertilized eggs on a molasses-agar base flown for 10-14 days. The experiments are compatible only with a Shuttle-sortie mission or with an orbital facility capable of automatic sample return. Package parameters are:

	Each Package	Total (4)
Weight:	0.7 kg (1.5 lb)	2.8 kg (6 lb)
Volume:	0.03 m^3 (1 ft^3)	0.12 m^3 (4 ft^3)
Envelope:	TBD	TBD

The preferred equipment for study of mating behavior, fertility and development is a group of breeding containers used serially for full-cycle reproduction of the gnats. Four breeding containers each containing 10 males and 10 females on a molasses-agar base will be used for each generation to permit comparison of replicates and prevent loss of the experiment through single container failure. Assuming a minimum of 10 days per generation, the research would require use of a minimum of 8 reusable

containers or 36 expendable containers over the required 90-day flight research period. Package parameters are:

	Each Breeding Container	Total Reusable (8)	Total Expendable (36)
Weight:	TBD	TBD	TBD
Volume:	TBD	TBD	TBD
Envelope:	TBD	TBD	TBD

All packages will be coupled to the CORE for research programming command purposes, and for management of environmental data readout from the packages, including at least temperature, humidity, gas composition, vibration, g-environment, etc.

In the longevity experiment the CORE will also provide recording and data management of output signals from the individual activity monitors, photographic and lighting facilities, and recording capability for crew verbal and written observations. All nonphotographic data will be dumped each orbit. Photographs will be developed onboard to prevent record loss and for confirmation of crew visual observations. The CORE "glove box" will be employed to provide sterile conditions for daily opening of the longevity package, testing for moribund gnats, and ad hoc removal of dead specimens. The preservation unit of the CORE will be used for preservation of the dead gnats by means of chemical fixatives and/or freezing techniques for return to Earth for detailed study.

Simple mating, embryology and development experiments will place essentially the same demands on the CORE. The major differences will be that removal of live samples in these experiments will be on a planned daily schedule and that the CORE must provide equipment for CO_2 anaesthesia of specimens and for live preservation of a portion of the specimens, in the state in which they were removed, for continued live development and mating studies after specimen return to Earth.

Long-term mating, embryology, and development research will place further requirements upon the CORE. In addition to those listed above, the CORE must provide optical magnifiers to facilitate segregation of adult males and females. The principal added requirement for the CORE is imposed if reusable breeding packages are employed, necessitating equipment for cleaning, sterilizing, recharging, maintaining, repairing, and checking out the reusable packages.

The package(s) will be held in the Common Experiment Housing which will provide for control of temperature, humidity, gas composition and other common ECS parameters. Gaseous and/or liquid expendables will also be provided by the Common Experiment Housing. Environmental condition sensors will be part of the package, but their output

will be commutated by the Housing Unit and fed to the CORE for recording and for correction-calculations and commands.

Experiment-peculiar equipments are:

a. Longevity research package, a container capable of housing 250 adult gnats in individual "cells," each provided with a molasses-agar food base. The container will maintain a sterile interior, have an optically flat transparent face for experimenter observation and photographic recording of the specimens, and will be capable of being opened for access to specimens. Activity monitors will be provided for each of the cells. Output preamplification of the activity monitor signal and readout commutation across all cells will be incorporated in the longevity research package. The amplified output will be fed to the CORE data management center for processing.

b. Breeding cage, a container capable of housing 20 adult gnats on a sterile molasses-agar base. It will provide for visual and photographic access. Activity monitors and their associated amplification equipment will be integral to the package. The cage will maintain males and females in separate compartments until a selected breeding time. The cage will be capable of being opened under sterile conditions for removal of adults and samples of eggs, larvae, pupae, and newly emerged adults. This container may be either totally expendable, totally reusable, or partially reusable, i.e., a reusable container with an expendable growth-medium recharging kit.

5.4.1.1.3 Observation/Measurement Program. The following program will be required as a minimum for the determination of longevity, behavior, histological and biochemical characteristics:

a. Measure all environmental parameters once per hour.

b. Photograph each package four times daily.

c. Record visual observations of behavior four times daily.

d. Count individual gnats (alive/moribund/dead) four times daily.

e. Record gnat activity measures continuously until death.

f. Return preserved specimens to Earth after 90 days.

To determine mating, behavior, fertility and development, the observation/measurement program described above (a-e) will be accomplished. In addition this research requires:

a. Record time and numbers of eggs deposited four times daily.

b. Record time and percent of hatching, moulting, pupation, eclosion, and mating four times daily.

c. Return live (dormant or active) and preserved specimens to Earth after 90 days.

5.4.1.1.4 Interface Support and Performance Requirements. General environment requirements are:

Temperature: 296 ± 1°K (74 ± 2°F)

Relative Humidity: 50 ± 20%.

Total Pressure: One Earth atmosphere.

O_2N_2 Ratio: 20% to 80%.

Other Gases: CO_2 < 1 mm Hg

Thermal Output: TBD

Unique environment requirements are:

a. Acceleration: 10^{-5} g or less 95% of the time; 10^{-3} g or less 5% of the time.

b. Vibration: TBD (minimum).

c. Rhythmic Phenomena: Minimum allowable (TBD).

d. E-M Phenomena: Earth normal.

Power required is 20 watts.

Data management requirements are:

a. Command: TBD

b. Readout:

Digital: TBD

Analog: TBD

Other: 1560 photos
TBD verbal record tapes

Crew support requirements are:

a. Experiment setup (longevity and minor reproduction and development): 8 hr, once/90 days.

b. Experiment setup (major reproduction and development): 8 hr ea., 10 setups.

c. Research activities:

Photography: 20 min/event, 4 events/day, 90 days.

Visual observations and removal of live and dead samples: 1 hr/event, 4 events/day, 90 days.

d. Experiment termination (shutdown, logistics loading and equipment refurbishment): 8 hr/event, 11 events/90 days.

e. Skill level: Highly trained biology technician (early); professional invertebrate physiologist (later).

Orbital Altitude and Inclination is N/A.

Prelaunch and launch requirements are maintenance of package integrity; maintenance of temperature, pressure, relative humidity, etc.; and prevention of exposure to toxic environmental factors.

Reentry and post-reentry requirements are the same as prelaunch requirements, plus return to ground study laboratory within 12 hours after reentry.

5.4.1.1.5 Potential Role of Man. Man's potential role in both short-term and long-term studies is typified by the outline of activities proposed below:

a. Offload experiment-peculiar equipment and specimens from logistics carrier.

b. Install experiment-peculiar equipment and specimens in the Invertebrate Common-Experiment Package Housing.

c. Couple all appropriate connections between experiment equipment, common housing and CORE.

d. Complete checkout.

e. Initiate experiment cycle by computer command and by manual confirmation of command execution.

f. Continue surveillance of computer commanded or controlled activities, correct, align, maintain and repair throughout 90-day research period.

g. Photograph all gnats in containers at specified intervals.

h. Observe level of activity and other aspects of behavior at specified intervals.

i. Open containers, perform research manipulations (glove box) and return containers to the Common Package Housing under sterile conditions. For longevity studies, test for moribund gnats, remove dead gnats ad hoc, and preserve dead gnats with chemical fixatives or freezing. For short-term reproduction, embryology and development studies remove adults after eclosion and egg deposition and preserve adults alive but dormant for Earth-surface study or with chemical

fixatives or freezing; record time and quantity of eggs laid, record time and percent of hatch, moult, pupation and eclosion, and remove samples of eggs, larvae and pupae on preset schedule. For long term reproduction, embryology and development studies remove initial adults after egg deposition, preserve initial adults as above; on F_1 generation, record time and quantity of eggs laid, record time and percent of hatch, moult, pupation and eclosion, remove samples of eggs, larvae and pupae on preset schedule, remove F_1 adults and segregate sexes, install F_1 adults in clean sterile breeding cages, and clean, maintain, repair, sterilize and recharge the reusable breeding cage after F_1 use or prepare new expendable breeding cage for F_3 use; F_2 through F_9 generations, follow same procedure.

j. Record verbal notes and prepare written experiment log.

k. Develop photos and store for return to Earth.

l. Transmit selected photos via Earth downlink to P. I. team for review and decision on ad hoc experiment protocol revision.

m. Redirect experiment protocol as required by P. I. team.

n. Terminate equipment.

o. Prepare specimens, photos, tapes, logs, etc. for logistics return.

p. On-load experiment gear into logistics carrier.

5.4.1.1.6 Available Background Data. The sole NASA source is the Experiment Sheet, same title, provided by Ames Research Center. A Principal Investigator's proposal has been received by NASA.

5.4.1.2 Space Flight Effects of Aging and Longevity. The scientific objective of this experiment is to observe the effects of space flight conditions upon embryonic development, longevity, and aging of motor ability of the house fly.

5.4.1.3 Effect of Weightlessness on Regeneration of Planaria. The objective of this experiment is to establish the effects of weightlessness on regeneration, a process of importance in establishing the mechanism of organism self-repair in the normal environment.

5.4.2 EFFECT OF THE SPACE ENVIRONMENT ON INVERTEBRATE BEHAVIOR. The scientific objective of this experiment class is to detect, quantify and determine mechanisms involved in the modification of invertebrate behavior by exposure to the space environment. It is anticipated that the absence of various Earth normal cues will produce changes in such components of behavior as activity level, locomotion, sensory perception/response, orientation, communication, and social structure. Understanding the effects of removal of normal Earth surface cues should provide greater insight into the mechanisms underlying normal invertebrate behavior. An experiment requirements summary for this class is presented in Table 5-6.

Table 5-6. Experiment Requirements Summary (Class: Effect of the Space Environment on Invertebrate Behavior)

EXPERIMENT NO. AND TITLE	5421 Circadian Periodicity of Cockroach Activity and Respiration		5422 Circadian Rhythm of Vinegar Gnat Eclosion		5423 Effect of Weightlessness on Web-Building Behavior of Spiders										NOTES
SPECIMEN	American Cockroach		Vinegar Gnats		Araneus diademaius Spider										
LOCATION	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	
NO. OF SPECIMENS [11]	TBD	TBD	TBD	TBD	TBD	TBD									[1] No periodic cues at whole-number fractions of 24 hours.
HOLDING CAGES															[2] Normal Laboratory
Standard															Max.: $\begin{cases} 10^{-4}g\ 95\%\ \text{of time} \\ 10^{-3}g\ 5\%\ \text{of time} \end{cases}$
Metabolic															[3] Ad Hoc observations required up to 8 hr/day. They cannot be scheduled and are part of the daily average. Crew time is average.
Colony															[4] SMAC = Space maximum allowable concentration for man.
MAN REQUIREMENTS, hr															[5] No offensive or noxious odor.
Skill 1															[6] TBD; minimal to reasonable engineering design effort.
Setup	4	8	2	4	1	2									[7] Arterial & Venous
Daily Average [3]	0.6	1.2													[8] Includes blood, feces, urine, bacterial, gas, and biopsy samples.
Terminate	4	8			1	2									[9] Samples per week/ tests per sample
Skill 3															[10] Measurements made at holding unit level only; () = each organism.
Setup															[11] Plus progeny.
Daily Average [3]															[12] Must be returned to lab in 88 hrs.
Terminate															
Skill 4															
Setup															
Daily Average [3]															
Terminate															
EXPERIMENT DURATION, days	180 to 360	180 to 360	21	21	90	90									
ENVIRONMENTAL REQMTS															
pO_2, mm Hg	150±10	150±10	150±10	150±10	150±10	150±10									
Total Pressure, mm Hg	760±10	760±10	760±10	760±10	760±10	760±10									
pCO_2, mm Hg	TBD	TBD	<7	<7	<7	<7									
pCO, mm Hg															
pNH_3, mm Hg															
pH_2O, mm Hg	*	*	**	**											
Temperature, °K (°C)	288&298 (15&25)	288&298 (15&25)	283&293 (10&20)	283&293 (10&20)	(25) 298	(25) 298									
O_2 Consumption, kg day	Negl	Negl	Negl	Negl	Negl	Negl									
CO_2, kg day	Negl	Negl	Negl	Negl	Negl	Negl									
Noise, dB	[1]	[1]	[1]	[1]	[1]	[1]									
Vibration, g (Hz)	[1]	[1]	[1]	[1]	[1]	[1]									
Acceleration, g	[2]	1	[2]	0.5 & 1	[2]	0.5 & 1									
Radiation, C/kg	[6]	[6]	[6]	[6]	[6]	[6]									
Illumination, lum/m^2 (ft-c)															
Trace Contaminants	[4]	[4]	[4]	[4]	[4]	[4]									
NUMBER AND FREQUENCY OF MEASUREMENTS															*8-12 and 14-21 **5-8 and 11-16

Table 5-6. Experiment Requirements Summary (Class: Effect of the Space Environment on Invertebrate Behavior), Contd

EXPERIMENT NO.	5421		5422		5423										NOTES
LOCATION	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	
NUMBER AND FREQUENCY OF MEASUREMENTS															
Samples [8] Prep for Earth Return/wk															
pO_2, hourly	X 3X/hr	X 3X/hr	X	X	X	X									
pCO_2, hourly [10]	X 3X/hr	X 3X/hr	X	X	X	X									
pNH_3, hourly [10]	X 3X/hr	X 3X/hr													
pH_2O, hourly [10]	X 3X/hr	X 3X/hr	X	X	X	X									
Temp., hourly [10]	X 3X/hr	X 3X/hr	X	X	X	X									
Noise, continuous [10]	X 3X/hr	X 3X/hr	X	X	X	X									
Vibration, cont. [10]	X 3X/hr	X 3X/hr	X	X	X	X									
Acceleration, cont. [10]	X 3X/hr	X 3X/hr	X	X	X	X									
Radiation, cont. [10]	X 3X/hr	X 3X/hr	X	X	X	X									
Organism Sacrifice/wk															
Urine Analysis/wk															
Organism Visual Monitorings/wk															
Organism Recovery Preparation, No.															
Organism Live Recovery, No.															
Illumination, No./meas.															
Radiobiologies/wk															
Crew Observations/day	1	1	48	48	1	1									
Eclosion Count			X*	X*											*Ea 20 Min
Activity, continuous	X	X													
Organism Preservation															
Organism - Earth Return															
Oviposition Observations per Day															
Status - Alive/Moribund/Dead, Obs/Day	X	X	X	X	X	X									
Event Start/Stop	X	X	X	X	X	X									
Respiration Rate	X	X													
POWER															OTHER
AC															
Continuous, watts															
Peak, watts															
Peak Duration, min/day															
DC															
Continuous, watts	25	50	25	50	10	20									
Peak, watts															
Peak Duration, min/day															
WEIGHT															
Organisms and Cages, kg (lb)	23 (50)	46 (100)	5 (11)	10 (22)	10 (22)	20 (44)									
Ancillary Research Equipment, kg (lb)	2 (4.4)	4 (8.8)	1 (2.2)	1 (2.2)	2 (4.4)	2 (4.4)									
VOLUME															
Organisms and Cages, m^3 (ft^3)	0.06 (2)	0.12 (4)	0.02 (0.7)	0.04 (1.4)	0.05 (1.8)	0.10 (3.5)									
Ancillary Research Equipment, m^3 (ft^3)	0.02 (0.7)	0.02 (0.7)	0.01 (0.35)	0.01 (0.35)	0.01 (0.35)	0.01 (0.35)									
LOGISTICS															
Weight at Launch, kg (lb)	25 (55)	50 (110)	6 (13.2)	11 (24.2)	12 (26.4)	22 (48.4)									
Supplies/Mo. Up, kg (lb)	1 (2.2)	1 (2.2)	1 (2.2)	1 (2.2)											
Supplies/Mo. Down, kg (lb)	0.8 (1.7)	0.8 (1.7)	0.8 (1.7)	0.8 (1.7)											
Weight at Termination, kg (lb)	25 (55)	50 (110)	6 (13.2)	11 (24.2)	12 (26.4)	22 (48.4)									
Volume at Launch, m^3 (ft^3)	0.09 (3.2)	0.18 (6.4)	0.03 (1.1)	0.05 (1.8)	0.06 (2.1)	0.11 (3.9)									
Supplies/Mo. Up, m^3 (ft^3)	0.01 (0.35)	0.01 (0.35)	0.01 (0.35)	0.01 (0.35)											
Supplies/Mo. Down, m^3 (ft^3)	0.01 (0.35)	0.01 (0.35)	0.01 (0.35)	0.01 (0.35)											
Volume at Termination	0.08 (2.8)	0.16 (5.6)	0.03 (1.1)	0.05 (1.8)	0.06 (2.1)	0.11 (3.9)									
Frozen Specimens Down															
Live Organisms Up	X	X	X	X	X	X									
Live Organisms Down	X	X			X	X									
Frozen Specimens Up															
Other Film					X	X									
COMMUNICATIONS															
Voice, hr/day	TBD	TBD	TBD	TBD	TBD	TBD									
TV, B&W, hr/day	X	X	X	X	X	X									
TV, Color, Ad Hoc	X	X	X	X	X	X									

5.4.2.1 Circadian Periodicity of Cockroach Activity and Respiration

5.4.2.1.1 Scientific Objectives. The proposed experiment will test the premise that circadian periodicity of organisms removed from terrestrial stimuli will degrade. The purposes of this experiment are to 1) examine the persistence and precision of the circadian period of cockroach activity and metabolic rate, and 2) examine the phenomena of temperature compensation of circadian periodicity when all geophysical variables other than light and temperature are either removed or sensed by the organism at periods other than 24 hours. This approach is particularly significant in view of laboratory data which has revealed that animals maintained in a free-running condition for several months will often display desynchronized periodicities. The question asked regarding the effect of prolonged space flight on circadian systems ultimately must be attacked in deep space probes. However, both orbital and deep space missions are important. If a circadian periodicity persists in Earth orbit but decays in distant solar orbits, we would have direct evidence, available from no other combination of experiments, that geophysical periodicities are essential inputs for maintenance of circadian organization.

5.4.2.1.2 Description. Two groups of six cockroaches (Periplaneta americana) each will be employed. One group will be held at 288°K (15°C) and the other group at 298°K (25°C). The frequency of activity and respiratory rate will be monitored at 20-minute intervals. The data upon retrieval will be examined to determine the precision and persistence of the circadian period as a function of temperature. Data will be compared with ground-based control data for evidence of entrainment to a precise 24-hour period.

The minimum duration of the experiment is 180 days, the maximum 360 days. As a consequence, the roaches may be manipulated in various ways depending upon the nature of the retrieved data. To facilitate rephasing of circadian periods, provisions will be made to alter both the temperature and photoperiod upon ground command. It is essential that ground controls be run simultaneously with the flight experiment.

The roaches will be "housed" in activity wheels in an oxygen-demand-type environmental control system. The number of activity wheel half-revolutions are counted in digital counters, and serially shifted to a core memory every 20 minutes. Similarly, a respirometer based on monitoring the regulator for the O_2 demand system will be provided and monitored at 20-minute intervals. Ambient pressure and temperature for each specimen chamber is sampled directly at least once per hour. Package parameters are:

	Each Package	Total
Weight:	10 kg (22 lb)	20 kg (44 lb)
Volume:	0.03 m^3 (1 ft^3)	0.06 m^3 (2 ft^3)
Envelope:	TBD	TBD

This experiment should be conducted both in Earth orbit and in deep space. Assuming the data show dependency of the circadian organization on geophysical cues, further experiments will attempt to identify the specific cues involved and the mechanisms by which living systems sense the cues.

All packages will be coupled to the CORE for research programming command purposes (e.g., general ECS cycling, light-dark cycles, thermal changes), and for management of environmental data read out from the packages, including at least temperature, light-dark cycle times, humidity, gas composition, vibration, and g-environment. The CORE will also provide recording and data management of output signals from the individual activity-wheel monitors and from the individual respirometers, and recording facilities for crew written and verbal records. All data will be dumped each orbit.

The packages will be held in the Invertebrate Common Experiment Package Housing which will provide for control of temperature, humidity, gas composition and other common ECS parameters. Gaseous and/or liquid expendables will also be provided by the Common Experiment Housing. Environmental condition sensors will be part of the package, but their output will be commutated by the Housing Unit and fed to the CORE for recording and for correction calculations and commands. Power will be provided to the individual insect packages through the Common Experiment Housing.

Experiment-peculiar equipment includes the activity wheels, the activity monitors, and the individual respirometers which will be integral parts of the insect package. However they may be adapted for use by a number of invertebrate species.

5.4.2.1.3 Observation/Measurement Program. The following program will be required as a minimum:

a. Start up experiment after achieving orbit.

b. Measure all environmental parameters once per 20 minutes.

c. Measure activity and respiration rate once per 20 minutes.

d. Return data to Earth once daily.

e. Rephase or re-entrain to new photoperiod and continue observations.

f. Adjust to new experimental temperature regimes.

g. Terminate experiment and return live specimens to Earth.

5.4.2.1.4 Interface Support and Performance Requirements. General environment requirements are:

a. Temperature (internal to experiment): Initial, 288°K (15°C ± (TBD)) and 298°K (25°C ± (TBD)); contingent, variable to 303°K (30°C).

b. Relative Humidity: 60-90%.

c. Total Pressure: One Earth atmosphere.

d. O_2/N_2 Ratio: 20%/80%.

e. Other Gases: TBD.

f. Thermal Output: TBD.

Unique environment requirements are:

a. Complete isolation from rhythmic phenomena.

b. Vibration: TBD (minimum).

c. Acceleration: Not to exceed 1g. Any value less than 1g is acceptable, but must be either random or constant in order to avoid inadvertent rhythmic cues.

Power required is 25 watts at 27.5 ± 2.5 Vdc.

Data Management Requirements:

a. Experiment Data: 3 analog channels, 0-3 volts; 2 eight-bit words, 0-5 volts; commutate 3 times per hour.

b. Data dump once per day.

c. Command requirements: 10 commands; change temperature or photoperiod once monthly.

Crew support requirements are:

a. Experiment setup: 4 hours; once/180 days (360 days).

b. Research activities:

 1. Monitoring experiment: 10 min; 4 times daily; 180 days (360 days).

 2. Maintenance and repair: TBD.

 3. Revise research program profile: 4 hours; once/month; 6 months (12 months).

 4. Experiment termination: 4 hours; once/180 days (360 days).

c. Skill level: Biology technician and expert electrical, electronic, mechanical, etc. technician.

Orbital altitude and inclination are N/A.

Prelaunch and launch requirements are:

a. Maintenance of package integrity.

b. Isolation from rhythmic phenomena.

c. Maintenance of temperature, pressure, relative humidity, etc.

d. Prevention of exposure to toxic environmental factors.

Reentry and post-reentry requirements are the same as for prelaunch and launch, plus return to ground study laboratory within 12 hours after reentry.

This experiment illustrates the combination of two extremes. The mission profile and the programming of experiments are profoundly impacted by the requirement that this experiment be accommodated onboard for a very long time, perhaps over the length of several crew-duty cycles. Occupying, as it does, the common-use and general-purpose equipment for this period of time forces the decision to provide more accommodation or to reduce the number of invertebrate experiments accommodated during this period. Crew involvement is minimal. The simplicity of the experiment and the need to avoid introduction of artifacts due to research operations minimize man's role. Yet, despite reliability of equipment, preventive maintenance and repairs will undoubtedly be required. Achieving randomness in preventive maintenance and precluding interference with the experiment during repairs or research operations provide a unique challenge to the system developer.

5.4.2.1.5 Potential Role of Man. Man's potential role is minimized to avoid introduction of experiment artifacts during servicing or research operations. Man's role will be approximately the following:

a. Offload experiment-peculiar equipment and specimens from logistics carrier.

b. Install experiment-peculiar equipment and specimens in the Invertebrate Common Experiment Package Housing.

c. Couple all appropriate connections between experiment equipment, common housing and the CORE.

d. Complete checkout.

e. Initiate experiment cycle by computer command and by manual confirmation of command execution.

f. Continue surveillance of computer commanded or controlled activities, correct, align, maintain and repair throughout 180 to 360 day research period.

g. Monitor experiment data output, i.e., insect activity levels and respiration rate.

h. Initiate changes in the temperature or light-dark cycle by computer command and manual confirmation of command execution.

i. Record verbal notes and prepare written experiment log.

j. Otherwise redirect experiment protocol as required by P.I. team.

k. Terminate equipment.

l. Prepare specimens, tapes, logs, etc. for logistics return.

m. On-load experiment gear into logistics carrier.

5.4.2.1.6 Available Background Data. The sole NASA source is the Experiment Sheet, same title, provided by Ames Research Center. A Principal Investigator's proposal has been received by NASA.

5.4.2.2 Circadian Rhythm of Vinegar Gnat Eclosion. The objective of this experiment is to measure the period of circadian rhythm in vinegar gnat pupae by studying the interval between successive bursts of eclosion.

5.4.2.3 Effect of Weightlessness on Web-Building Behavior of Spiders. This experiment's objective is to evaluate the importance of the direction of the gravity vector in web-building behavior of spiders.

5.4.3 EFFECT OF THE SPACE ENVIRONMENT ON INVERTEBRATE GENETICS. The scientific objective of this experiment class is to detect modifications in the genetics of invertebrates exposed to the space environment and to discover the mechanisms underlying these changes. It is anticipated that absence of Earth normal environmental conditions coupled with an increase in the radiation loading of the biological system will produce significant aberrations. Understanding the mechanisms by which aberrations due to weightlessness are produced should increase our understanding of genetics and especially of the role of gravity in maintaining normal genetic function. An experiment requirements summary for the class is in Table 5-7.

5.4.3.1 Combined Space and Irradiation Effects.

5.4.3.1.1 Scientific Objectives. Four objectives are involved in flight studies on the Flour Beetle (Tribolium):

a. Verify and extend earlier observations that the effect of radiation in producing developmental abnormalities and dominant lethal mutations is greater when radiation is administered while the organism is weightless than when it is administered at 1 g.

b. Observe special radiation effects due to heavy cosmic ray primaries.

c. Observe the effects of long-term weightlessness on population genetics, mating habits and metabolism of Tribolium.

d. Determine if the time development of the flour beetle is altered in the weightless condition.

Table 5-7. Experiment Requirements Summary (Class: Effect of the Space Environment on Invertebrate Genetics)

EXPERIMENT NO. AND TITLE	5431 Combined Space and Irradiation Effects		5432 Effects of Space Environment on Genetic Changes		5433 Genetic Effects of Space Flight on Sperm and Ovum		5434 Chromosome Rejoining at 0-g								NOTES
SPECIMEN	Flour Beetle		Vinegar Gnat		Vinegar Gnat		Vinegar Gnat								
LOCATION	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	
NO. OF SPECIMENS [11]	15	30													
HOLDING CAGES															[1] No periodic cues at whole-number fractions of 24 hours.
Standard															
Metabolic															
Colony	15	30													
MAN REQUIREMENTS, hr															[2] Acceleration
Skill 1															Max. $\begin{cases} 10^{-4} & 95\% \text{ of time} \\ 10^{-3} & 5\% \text{ of time} \end{cases}$
Setup	8	16	2	4	2										[3] Ad Hoc observations required up to 8 hr/day. They cannot be scheduled and are part of the daily average. Crew time is average.
Daily Average [3]	2	4	2	4	1	4	2	4							
Terminate	8	16	4	8	2	2	1	2							
Skill 3															
Setup						4	2	4							
Daily Average [3]															
Terminate															
Skill 4															
Setup	1				1	2									[4] SMAC = Space maximum allowable concentration for man.
Daily Average [3]	1	2	1	2	1	2									
Terminate	1	2			2	4									
EXPERIMENT DURATION, days	180	180	11-50	11-50	21-42	21-42	7-56	7-56							[5] No offensive or noxious odor.
ENVIRONMENTAL REQMTS															[6] TBD; minimal to reasonable engineering design effort.
pO_2, mm Hg	150±10	150±10	150±10	150±10	150±10	150±10	150±10	150±10							
pN_2 or Total Pressure, mm Hg	760±10	760±10	760±10	760±10	760±10	760±10	760±10	760±10							[7] Arterial & Venous
pCO_2, mm Hg															
pCO, mm Hg															[8] Includes blood, feces, urine, bacterial, gas, and biopsy samples.
pNH_3, mm Hg															
pH_2O, mm Hg	*	*	6-15	6-15	6-15	6-15	6-15	6-15							[9] Samples per week/ tests per sample
Temperature, °K (°C)	**	**	296±1 (23±1)	296±1 (23±1)	296±1 (23±1)	296±1 (23±1)	296±1 (23±1)	296±1 (23±1)							
O_2 Consumption, kg/day	N	N	N	N	N	N	N	N							[10] Measurements made at holding unit level only; () = each organism.
CO_2, kg/day	N	N	N	N	N	N	N	N							
Noise, dB	[6] [1]	[6] [1]	[6] [1]	[6] [1]	[6] [1]	[6] [1]	[6] [1]	[6] [1]							
Vibration, g (Hz)	[6] [1]	[6] [1]	[6] [1]	[6] [1]	[6] [1]	[6] [1]	[6] [1]	[6] [1]							
Acceleration, g	[7]	[7]													11 Plus progeny.
Radiation, C/kg															
Illumination, lum/m^2 (ft-c)															12 Must be returned to lab in 88 hrs.
Trace Contaminants	[4]		[4]		[4]		[4]								
NUMBER AND FREQUENCY OF MEASUREMENTS															
															* 2-8 5-13 8-24
															** 288 ± 0.5 (15 ± 0.5) 297 ± 0.5 (24 ± 0.5) 307 ± 1 (34 ± 1)
															N = Negligible.

Table 5-7. Experiment Requirements Summary (Class: Effect of the Space Environment on Invertebrate Genetics), Contd

EXPERIMENT NO.	5431		5432		5433		5434								NOTES
LOCATION	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	Lab Only	Lab + Centr	
NUMBER AND FREQUENCY OF MEASUREMENTS															
Samples [8] Prep for Earth Return/wk															
pO_2, hourly	X	X	X	X											
pCO_2, hourly [10]	X	X	X	X											
pNH_3, hourly [10]															
pH_2O, hourly [10]	X	X	X	X											
Temp., hourly [10]	X	X	X	X											
Noise, continuous [10]	X	X	X	X											
Vibration, cont. [10]	X	X	X	X											
Acceleration, cont. [10]	X	X	X	X											
Radiation, cont. [10]	X	X	X	X											
Organism Sacrifice/wk															
Urine Analysis/wk															
Organism Visual Monitorings/wk															
Crew Observations/Day	1	1	1	1	1	1									
Activity, continuous	X	X													
Organism - Earth Return	X	X	X	X	X	X									
Oviposition Observations/Day															
Status - Alive/Moribund/Dead, Obs/Day	X	X					X	X							
Event Start/Stop	X	X	X	X											
Histologies	X	X					X	X							
Eclosion Rate	X	X													
Radiation Exposure	X	X	X	X	X	X									
Chemical Analysis	X	X													
Gross Microscopy	X	X			X	X									
Specimen Preservation	X	X	X	X	X	X									
Photography	X	X													
Biochemistries	X	X													
Subcultures	X	X					X	X							
POWER															OTHER
AC															
Continuous, watts															
Peak, watts															
Peak Duration, min/day															
DC															
Continuous, watts	150	300	15	30	10	20	10	20							
Peak, watts															
Peak Duration, min/day															
WEIGHT															
Organisms and Cages,	22	45	5	10	7	13	7	13							
kg (lb)	(50)	(100)	(11)	(22)	(15)	(30)	(15)	(30)							
Ancillary Research	2	4	2	4	2	4	2	4							
Equipment, kg (lb)	(4.4)	(8.8)	(4.4)	(8.8)	(4.4)	(8.8)	(4.4)	(8.8)							
VOLUME															
Organisms and Cages,	0.1	0.2	0.05	0.10	0.05	0.1	0.05	0.1							
m^3 (ft^3)	(3.5)	(7.0)	(1.8)	(3.5)	(1.8)	(3.5)	(1.8)	(3.5)							
Ancillary Research	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01							
Equipment, m^3 (ft^3)	(0.35)	(0.35)	(0.35)	(0.35)	(0.35)	(0.35)	(0.35)	(0.35)							
LOGISTICS															
Weight at Launch,	25	50	8	15	10	15	10	15							
kg (lb)	(55)	(110)	(17.6)	(33)	(22)	(33)	(22)	(33)							
Supplies/Mo. Up,	1	1	1	1	1	1	1	1							
kg (lb)	(2.2)	(2.2)	(2.2)	(2.2)	(2.2)	(2.2)	(2.2)	(2.2)							
Supplies/Mo. Down,	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8							
kg (lb)	(1.8)	(1.8)	(1.8)	(1.8)	(1.8)	(1.8)	(1.8)	(1.8)							
Weight at Termination,	25	50	8	15	10	15	10	0.5							
kg (lb)	(55)	(110)	(17.6)	(33)	(22)	(33)	(22)	(1.1)							
Volume at Launch,	0.12	0.22	0.07	0.12	0.07	0.12	0.07	0.12							
m^3 (ft^3)	(4.2)	(7.8)	(2.5)	(4.2)	(2.5)	(4.2)	(2.5)	(4.2)							
Supplies/Mo. Up,	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01							
m^3 (ft^3)	(0.35)	(0.35)	(0.35)	(0.35)	(0.35)	(0.35)	(0.35)	(0.35)							
Supplies/Mo. Down,	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01							
m^3 (ft^3)	(0.35)	(0.35)	(0.35)	(0.35)	(0.35)	(0.35)	(0.35)	(0.35)							
Volume at Termination	0.12	0.22	0.07	0.12	0.07	0.12	0.07	0.12							
	(4.2)	(7.8)	(2.5)	(4.2)	(2.5)	(4.2)	(2.5)	(4.2)							
Frozen Specimens Down	X	X	X	X	X	X	X	X							
Live Organisms Up	X	X	X	X	X	X	X	X							
Live Organisms Down	X	X	X	X	X	X	X	X							
Frozen Specimens Up															
Other															
COMMUNICATIONS															
Voice, hr/day	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD							
TV, B&W, hr/day	X	X	X	X	X	X									
TV, Color, Ad Hoc	X	X	X	X	X	X									

5.4.3.1.2 Description. Radiation/weightlessness interaction effects on genetics, embryogenesis, development behavior and reproduction involves three studies:

a. Pupal studies. A minimum of 30 groups of 300 Tribolium pupae each, will be employed in this experiment. The culture medium will be flour. Individual modules will be used to house each group of insects. Fifteen groups will be maintained weightless and 15 will be maintained at 1 g in an FPE-peculiar housing unit including a small 1-g centrifuge. Three ages of pupae (1, 3 and 5 days) will be used and five beta radiation dose levels, 0, 0.348, 0.387, 0.425 and 0.464 C/kg (0, 1350, 1500, 1650 and 1800 R) will be employed. Irradiation will be accomplished in orbit. This set of 30 block treatments provides only for a single replicate of the experiment. Two or more replicates would be preferable to provide increased statistical confidence and to avert experiment loss due to single experiment failure. The experiment is to be run a minimum of 28 days.

b. Egg studies. A minimum of 30 groups, of 300 Tribolium eggs each, will be employed. The same equipment is used as for pupae studies; 15 groups will be held weightless and 15 at 1 g. The egg ages will be 1, 3, and 5 days; the beta radiation doses will be 0, 0.116, 0.181, 0.258, and 0.387 C/kg (0, 450, 700, 1000, and 1500 R), administered in orbit. Additional replicates would be desirable for statistical purposes and to prevent experiment loss from single equipment failure. The egg experiment is to be run a minimum of 60 days.

c. LET Studies: A minimum of two groups, of 300 Tribolium pupae each, will be exposed to high linear energy transfer (LET) particles (i.e., heavy cosmics) in the space vehicle environment. One group will be held weightless, the other in the small 1-g centrifuge. The culture medium will be flour. The pupae will be held firmly in a single position so that plastic dosimeters can show the relation of particle track to damage site in each insect. Two or more replicates of these groups would be desirable to increase statistical confidence and to prevent loss of the experiment by single equipment failure. Effects of high LET particles impacting during the pupae stage (the first 10-11 days) will be compared with those arriving during the adult stage. The total experiment will last at least 60 days.

Effects of weightlessness on population genetics and dynamics, mating habits, metabolism, embryology morphogenesis and development employs a minimum of two groups of 100 immature adult Tribolium each. The culture medium will be flour. One group will be held weightless and the other maintained at 1 g in an FPE-peculiar housing unit containing a small 1-g centrifuge. Using an appropriate temperature regime, at least two and possibly three generations of Tribolium can be reared through the larval stage in 90 days. It would be preferable to carry this type of experiment for at least 180 days to permit 5-6 generations of Tribolium to emerge. Especially desirable for studies of population genetics and dynamics is adequate time for cumulative effects to appear due to somatic genetic failures, other somatic intracellular changes or changes in intercellular or tissue relations to appear in the test specimens.

All insect containers will be coupled to the CORE for research programming command purposes (e.g., ECS cycling) and for management of environmental data readout from the containers, including at least temperature, humidity, gas composition, vibration, g environment, and ambient radiation level.

In radiation/weightlessness interaction studies the CORE will also provide recording and data management of automated observations such as radiation dosimetry from active dosimeters or insect activity if measurements are made, for instance, by sound signatures of insect movements. Storage for the onboard radiation source will be furnished. Gas samples collected periodically from individual insect modules will be transferred to the CORE for immediate chemical analysis to determine buildup of toxic contaminants, etc., and/or for storage and postflight analysis. A glove box will be required for opening the insect modules periodically for removal of insect specimens (dead and live) and removal of aliquots of the culture medium for onboard chemical analysis (CORE) or storage for postflight analysis.

Microscopy facilities for gross anatomical examination of test specimens will be required. Equipment will be needed for preservation of live specimens in cold storage (for subsequent examinations, development and breeding on Earth) and in selected cryogenic or chemical fixatives. Photographic services will be needed for onboard recording of specimen condition as well as facilities for recording verbal and written observations by the onboard investigator. Facilities for maintenance, repair, and checkout of the insect housing-centrifuge and insect modules will be required.

High LET particle studies will require CORE support and the radiation unit plus the equipment necessary for removal and storage of the special plastic dosimeters used in this work.

Population studies on the effects of weightlessness over several generations of Tribolium will require all CORE support described above, omitting all radiation-associated support except the active dosimetry of the ambient radiation environment. The glove box of the CORE must be provided with equipment for separating eggs, larvae, pupae and adults from the flour culture medium. Optical equipment will be required for counting eggs and larvae as well as gross anatomical examination of the later stages for observing morphological abnormalities and for sexing pupae. The glove box must be equipped for innoculating flour with the appropriate number of eggs for F, and succeeding generations. The CORE will also support the investigator in visual observation and photographic recording of behavioral characteristics such as locomotion, reproduction, tropisms, etc. Use of CORE equipment for the removal, analysis and preservation of sample specimens and substrates is cited above. If reusable breeding containers are to be used, the CORE will be required to support cleaning, maintenance, repair, checkout and sterilization of these special containers.

FPE-peculiar equipment described is originally intended for Tribolium studies. However, with appropriate design, a variety of insect species can be supported in appropriate substrates for diverse research purposes in Earth orbit.

The 0-g/centrifuge mount for the insect modules will be held in the Common Invertebrate Experiment Housing which will provide for control of temperature, humidity, gas composition, other common ECS parameters, noise, vibration, light, etc. Gaseous and/or liquid expendables will also be provided by the Common Housing. Environmental condition sensors will be part of the individual insect modules or containers, but their output will be transceived by the Common Housing to the CORE for recording, correction calculations, and adjustment commands in a feedback loop. Certain experiment observations will be handled in a similar fashion. The Common Housing will be coupled to the CORE and the insect containers to permit periodic sampling of the gas in the insect containers and transfer to the CORE for storage and/or analysis of toxic compounds.

The invertebrate 0-g/centrifuge mount consists of two cylinders mounted on a common axis. The cylinders are slotted to hold the insect irradiation/holding modules or the breeding containers. One cylinder is static; the other is rotated at approximately 10 radians/sec (95 rpm) to provide the control insects with a 1-g environment. Anti-noise and anti-vibration mounting are provided both externally and internally to the mount. ECS controls for individual insect modules may be a part of the 0-g/centrifuge mount. The mount will commutate all insect containers for ECS readout and control signals (coupling to the Common Housing and the CORE) for activity or other experiment data readout, and for periodic gas sample collection for CORE analysis or storage. The mount will accommodate the radiation source peculiar to this type of study. Special provisions are made for the mount to cool the insect specimens to the dormant stage (perhaps backed up by the Common Housing) and to warm them to their maximum normal metabolic level. Mount weight, volume and envelope parameters are:

	Each 0-g/Centrifuge Mount	Total
Weight:	20 kg (44 lb)	TBD
Volume:	0.025 m^3 (0.8 ft^3)	TBD
Envelope:	Cylinder 30 cm (1 ft) diam × 30 cm (1 ft) long	TBD

Insect radiation/weightlessness interaction modules will be rectangular in outline, and thin to permit uniform dosimetry with depth, with the broad face a segment of a cylinder conforming to the cylindrical surface of the mount. They will be built to accommodate passive dosimeters and can accommodate a variety of insect species and

stages in appropriate culture media. The modules will be cooled and warmed by heat transfer from the module mount. ECS monitoring sensors, activity monitors, and gas sampling devices will be built into the modules. The outputs will be commutated by the 0-g/centrifuge mount. The modules will be openable for removal of specimens and other samples. Module weight and dimensions are:

	Each Module	Total (30 min)
Weight:	0.2 kg (0.5 lb)	7 kg (15 lb)
Volume: *	21 cm^3 (1.25 in^3)	625 cm^3 (37.5 in^3)
Envelope: *	10 × 3 × 0.7 cm (4 × 1.25 × 0.25 in)	TBD

*Always operated or stored in the 0-g/centrifuge mount except during specimen removal, etc.

LET modules are identical to the radiation/0-g modules except that two special plastic slabs will be attached to each module to register the position and vector of each high LET particle penetrating the module. Since each insect will be fixed in place within the module, the track of each particle through an adult or a pupa can be determined. One of the plastic particle detectors will be removable so that hits received during the pupal stage only can be distinguished from those received after eclosion. Module weight and dimensions are:

	Each Module	Total (2 min)
Weight:	0.25 kg (0.5 lb)	0.5 kg (1 lb)
Volume: *	42 cm^3 (2.5 in^3)	84 cm^3 (5 in^3)
Envelope: *	10 × 3 × 1.4 cm (4 × 1.25 × 0.5 in)	TBD

*Always operated or stored in the 0-g/centrifuge mount except during specimen removal, etc.

Breeding container modules will contain essentially the same features as the radiation/0-g modules. The chief difference will be in the volume of medium accommodated. Breeding activities require a significantly greater volume. Moreover, since radiation exposures will not be made in these containers, the geometry is not critical.

	Each Module	Total (2 min)
Weight:	TBD	TBD
Volume: *	TBD	TBD
Envelope: *	TBD	TBD

*Always operated or stored in the 0-g/centrifuge mount except during specimen removal, etc.

Experiment-peculiar equipment is the radiation source. The source for Tribolium work could be used for a variety of research with this species; however, a change of species or of the main goals of the described experiment would require a change in source. Sr^{89} is the isotope of choice, considering species, stage, target density and depth. The source will contain 10 millicuries if a single experiment cycle is contemplated; further "runs" would require a stronger source or an isotope with a longer half-life. Simple aluminum shielding will suffice for onboard storage. Dosimetry will be by:

a. Calculations.

b. Thin LiF fluorescent dosimeters with a phantom.

c. In-flight monitoring with LiF or fluorescent glass.

d. Energy spectrum measurement with Si detectors.

e. Pulse height analysis.

Source weight and dimensions are:

	Source*
Weight:	2 kg (4.4 lb)
Volume:	$10^{-2} m^3$ (0.35 ft^3)
Envelope:	Cylinder 18 cm (7.1 in) dia. × 30 cm (11.8 in) long

*Requires shield during operation and shielded storage before and after.

5.4.3.1.3 Observation/Measurement Program. Observations and measurements made in all phases of study on Tribolium will be essentially the same. The program will include at least the following functions.

a. Measure all environmental parameters once per hour.

b. Photograph all insect modules on a planned schedule and ad hoc for unusual events.

c. Record visual observations of various forms of behavior on a planned schedule and ad hoc, e.g., locomotion, mating, tropism.

d. Test all specimens periodically for life state (alive/moribund/dead).

e. Record activity level continuously.

f. Record and photograph observable morphological abnormalities ad hoc.

g. Record time and numbers of eggs laid.

h. Record time and percent hatch, moulting, pupation, eclosion, mating, death, etc.

i. Determine sex ratio.

j. Perform onboard analysis of gas samples taken periodically from insect modules.

k. Return live and preserved specimens to Earth.

5.4.3.1.4 Interface Support and Performance Requirements. General environmental requirements are:

a. Temperature: Radiation/0-g interaction studies: 297 ± 0.5°K (24.0 ± 0.5°C)

High LET particle studies: 297 ± 0.5°K (24.0 ± 0.5°C)

Population genetics, dynamics, etc: 307 ± 1°K (34.0 ± 1.0°C)

Immobilization and dormancy of specimens: 288 ± 0.5°K (15.0 ± 0.5°C)

b. Relative Humidity: 20-60%

c. Total pressure: One Earth atmosphere

d. O_2:N_2 Ratio: 20%:80%

e. Other gases: Control CO_2, H_2S, C_2H_4, hydroquinones

f. Thermal input/output: TBD

Unique environment requirements are:

a. Acceleration: $<10^{-2}$ g at all times

b. Vibration: TBD (minimum possible)

c. Rhythmic phenomena: Nil allowable

d. E-M phenomena: not sensitive

Data Management requirements are:

a. Command functions: TBD

b. Readout: Digital: TBD

Analog: TBD

Other: Photos, TBD; verbal and written, TBD.

Crew support requirements are:

a. Experiment setup (All types of research): 8 hr/setup, minimum of 7/180 days.

b. Research activities:

1. Photography: 20 min/event; events/day TBD; 180 days.
2. Visual observations: 1 hr/event; events/day TBD; 180 days.
3. Removal of specimens and samples: 2 hr/event; 1 event/day; 180 days.
4. Analysis of gas samples: 4 hr/event; 1 event/week; 26 weeks.

c. Experiment termination (shutdown, logistics loading or equipment refurbishment and recharging): 8 hr/event; minimum of 7 events/180 days.

d. Skill level: Highly trained biology technician (early); professional invertebrate physiologist (later).

e. Orbital Altitude and Inclination (High LET particle studies only); 50° inclination.

Prelaunch and launch requirements are maintenance of insect module integrity and maintenance of temperature (288°K), pressure, relative humidity, etc.

Reentry and post-reentry requirements are maintenance of insect module integrity, maintenance of temperature (288°K), pressure, relative humidity, etc., and return to ground study laboratory within 12 hours of recovery.

5.4.3.1.5 Potential Role of Man. Man's potential role in all phases of Tribolium research is typified by the minimal outline proposed below:

a. Offload research specimens in modules or bulk transport container from logistics carrier.

b. Load specimens into modules and install in the 0-g centrifuge mount in the Invertebrate Common Experiment Package Housing.

c. Couple all appropriate connections between the specimen modules, the 0-g/centrifuge mount, the common housing and the CORE.

d. Complete checkout.

e. Initiate specific experiment cycle (warming of dormant specimens) by CORE computer command and by manual confirmation of command execution.

f. Unship radiation source and initiate onboard radiation exposure of specimens.

g. Terminate onboard irradiation of specimens and store radiation source.

h. Remove high LET particle detectors from insect modules.

i. Continue surveillance of computer commanded or controlled activities; correct, align, maintain, repair and checkout through 180-day research period.

j. Photograph all specimens at specified intervals.

k. Observe activity level and other aspects of behavior at specified intervals.

l. Open modules, perform research manipulations (in glove box) and return modules to the 0-g/centrifuge mount. For all studies, test periodically for moribund larvae, pupae and adults; remove dead insects and preserve with chemical fixatives or freezing. Remove adults (when required) after eclosion and egg deposition; preserve adults alive but dormant for Earth surface study or with chemical fixatives or by freezing; record time and quantity of eggs laid and time and percent of hatch, moulting, pupation and eclosion. Remove samples of live eggs, larvae, pupae, and adults on preset schedule. Note and photograph all abnormal specimens observed.

For studies requiring several generations of onboard breeding, remove F_1 pupae, segregate sexes, and install F_1 pupae in clean, breeding container. Clean, maintain, repair, recharge and checkout reusable breeding container after F_1 generation use or prepare, install and checkout expendable breeding container for next generation. Repeat sequence for F_2 to F_6 generations as applicable.

m. Record verbal notes and prepare written experiment log.

n. Develop photos and store for return to Earth.

o. Transmit selected photos, verbal notes, and written log information via Earth downlink to P. I. team for review and decision on ad hoc experiment redirection and protocol revision.

p. Redirect experiment as required by P. I. team.

q. Terminate experiment.

r. Prepare specimens, photos, tapes, logs, etc., for logistics return.

s. On-load experiment gear into logistics carrier.

5.4.3.1.6 Available Background Data. The sole NASA source is the experiment sheet, by the same title, provided by ARC. A Principal Investigator's proposal has been received by NASA.

5.4.3.2 Effects of Space Environment on Genetic Changes. Effects of weightlessness, radiation and chemical mutagens, separately and in combination, on the somatic and genetic cells of the vinegar gnat will be studied.

5.4.3.3 Genetic Effects of Space Flight on Sperm and Ovum. Study effects of space flight on adult reproductive cells by testing for recessive sex-linked lethals in both sperm and ovum.

5.4.3.4 Chromosome Rejoining at 0-g. Chromosomes are normally broken and then rejoined at fertilization. This study will be concerned with this phase of life cycle and effects of space flight on the chromosomes rejoining.

5.5 FPE INTERFACE, SUPPORT AND PERFORMANCE REQUIREMENTS

The summary data presented in Table 5-8 represents, in the best judgment of NASA scientists, the overall facility and experimental requirements to accomplish a realistic experimental program, and is based on some projection of the state-of-the-art. The rationale for selection of the summary parameters is in some instances arbitrary but has as a basis the total NASA experience and knowledge gained from prior flight and experiment definition and integration programs. The basis for each data entry is given in the notes.

Table 5-8. Invertebrate Research Facility FPE Summary Data

Weight, kg (lb)	2044 (4520)		Note 1
Volume, m^3 (ft^3)	14 (495)		Note 1
Power, watts	3273		Note 2
Crew Skills		1	Biological Technician
		2	Biochemist
		12	Electromechanical Technician
Data Rate, bps	277		Note 2
Analog Data: hours/day	1.6		
frequency, MHz	4		
Logistics Up, 30-day average, kg (lb)	22 (49)		Note 3
Logistics Down, 30-day average, kg (lb)			
1st 2 years	17 (38)		Note 4
3rd year on	20 (44)		Note 5
Pointing and Stabilization	NA		

Orbit Altitude & Inclination: High-Z cosmic ray exposure or certain insects requires the highest inclination possible.

Unique Environment Requirements: Isolation from rhythmic phenomena, noise, vibration, and possibly from EMI and ESI. Acceleration allowable at holding unit is $< 10^{-3}g$.

NOTES:
1. CORE units + FPE units + two logistic cycles of expendables + 1 complement of test subjects. Radiobiology unit and bioresearch centrifuge not included.
2. 40% of CORE units total + 75% of FPE units total = normal load.
3. 1% of FPE units + 80% of expendables to support total specimen holding capability + 16 2/3% specimen complement (equivalent to 50% replacement of specimens every 90 days).
4. 75% of logistics up.
5. 90% of logistics up.

5.6 POTENTIAL MODE OF OPERATION

The recommended mode of operation is within a general bioresearch laboratory facility. A bioresearch centrifuge attached to the general laboratory is required to provide artificial-g for biology specimens. Man will work at biological investigation and laboratory maintenance 8-24 hours per day. Preferred operation is manned continuous; however, by experiment selection, periods of unmanned operation or dormancy are possible.

Biological research is highly flexible in terms of procedures, specimens, and analytical location. Given a mission profile for a defined general laboratory, NASA scientists working with the PIs can frequently restate the hypothesis and develop a new protocol within that profile and still obtain valid data. However, the basic variables of gravity, radiation, and the absence of periodic cues must be met by the laboratory-provided environment.

With regard to specific Mode A, limited on-orbit stay time as with Space Shuttle, there are some experiments of less than 30 days duration which can be accommodated by this mode; but there are other experiments which require more than 30 days and cannot be accommodated. As for Mode B, extended on-orbit stay time, unmanned, with periodic revisits by Space Shuttle, there are some experiments which can be automated for accommodation by this mode, but the interval between crew visits should not exceed 30 days and a shorter interval such as 15 days is much preferred. Some experiments require Mode C, extended on-orbit stay time with Space Station, and this is the preferred mode for all experiments of this FPE.

5.7 ROLE OF MAN

Based on all activities in all experiments, man may potentially carry out the functions itemized below. In a high-load day in which contingencies call for the absolute maximum effort, the scientist may be required to devote 14 or more hours to experiment manipulations. These occasions will be infrequent, occurring mainly at experiment setup and termination times. In contrast with a fixed load on a minimum-effort day, considering only housekeeping and colony management, the scientist may be committed to as little as 2 hours' time, leaving him free for creative activities such as onboard data reduction and interpretation and planning of new and follow-on experiments. The average day, including housekeeping plus ad hoc research activities, will be 6 to 8 hours long.

a. Routine tasks (all experiments):

 1. Laboratory housekeeping, maintenance and repair.

 2. Experiment setup.

 3. Monitor organisms, hardware and data.

4. Experiment termination.

5. Specimen preparation for logistics return; package experiments, samples, photographs and other records for return to Earth.

b. Experiment peculiar research activities (desirable to enhance scientific value and responsiveness of experiment, but not critical to successful execution of basic experiment):

1. Set up follow-on experiments with tissue from prior experiments, onboard organisms, and/or newly arrived organisms.

2. Common lab techniques, e.g., mass measurement, fluid handling.

3. Perform laboratory analysis (biochemistries).

4. Gross morphological examination.

5. Cytological and histological preparations and preliminary analysis.

6. Programmed and ad hoc photography at request of P.I.

7. Ad hoc TV monitoring in conference with P.I.

8. Install and operate plate physiological and metabolic instrumentation, etc.

9. Radiobiology techniques -- administer and detect isotopic tracers.

10. Collect and preserve whole specimens.

11. Dissect and freeze specimens with dry ice or LN_2.

5.8 SCHEDULES

Estimates of development time required for the experiments described in this FPE are given in Table 5-9.

5.9 PRELAUNCH SUPPORT AND GSE

A common-use Life Sciences laboratory is required at the launch area to support the experiment packages and, in most cases, maintain sterility. It is suggested that this facility be sufficiently comprehensive to allow all the Principal Investigators and their research team to do all final assemblies and preparations.

A Life Sciences general ground control facility is required to provide a delayed simulation of the space bioresearch lab in terms of radiation, vibration, atmospheric composition, and man involvement. An optimum design is a duplicate facility of the space bioresearch lab, supported by the necessary radiation sources, mechanical actuation and bottle gas inventory, operated on the ground for all biological control. Separation of the FPEs in the control facility can introduce additional variables.

Table 5-9. Development Schedules

EXPT		1	2	3	4	5	6	YEARS
5.4.1.1	Longevity and Behavioral Changes in Space	←						
2	Space Flight Effects in Aging and Longevity	———						
3	The Effect of Weightlessness on Regeneration in Planaria	———	———	———	———	———		
5.4.2.1	Circadian Periodicity of Cockroach Activity and Respiration	———	———	———				
2	Circadian Rhythm of Vinegar Gnat Eclosion	———						
3	Effect of Weightlessness on Web-Building Behavior of Spiders	———	———	———				
5.4.3.1	Combined Space and Irradiation Effects	———						
2	Effects of Space Environment on Genetic Changes	———						
3	Genetic Effects of Spaceflight on Sperm and Ovum	———						
4	Chromosome Rejoining at 0-g	———						

The launch preparation facility and the ground control facility should be in the same complex. Direct link to mission control would provide communication with the space lab and the control facility and members of the experiment research staff.

5.10 SAFETY ANALYSIS

Safety hazards and precautions are listed in Table 5-10.

5.11 AVAILABLE BACKGROUND DATA

The experiment data has been provided by NASA Ames Research Center. The data is based on proprietary proposals received by NASA from Principal Investigators. Proposal data has been modified in some cases to fit the greater mission model provided by a general manned bioresearch laboratory as compared to Biosatellite missions.

Table 5-10. Safety Analysis

HAZARDS	PRECAUTIONS
Organism containers and incubators	
Exposure to cage atmosphere	Cage open operation performed in hooded work bench. Slight Δ P into cage.
Leaks from disconnects during cage removal.	Purge capability. Adequate contaminant removal system. Air flow adequate to move and trap free particles and debris. Vacuum cleaner to collect and remove free particles and debris.
Overpressurization of cage rack.	Pressure relief valve.
Experiment Procedures	
Chemical exposure.	Work in hooded work area. Purge capability. Use unbreakable containers. Inert atmosphere. Store in hermetically sealed cabinet which is purgable. Emergency life support.
Debris exposure.	Work in hooded work area. Adequate air flow to EC/LS. Emergency debris mask.
Cryogenic spillage.	Inert atmosphere. Purging capability. Emergency life support.

a. AIBS - Bioscience Research During Earth-Orbiting Missions: 1967 Regional Council studies in all disciplines.

b. Study of an Animal Research Facility for a Manned Orbital Biotech Lab, September 1967.

c. Experiment Implementation Plan for Manned Space Flight Experiments.

d. Biomedical Program for Extended Space Missions.

VOLUME VIII

SECTION 6

LIFE SUPPORT AND PROTECTIVE SYSTEMS

SECTION 6

LIFE SUPPORT AND PROTECTIVE SYSTEMS

6.1 GOALS AND OBJECTIVES

The objective of Life Support and Protective System (LSPS) technology is to provide a controlled and physiologically acceptable environment for flight crews during all phases of a space mission. The life support system must provide a long-term shirt-sleeve environment that also allows for pressure-suit operation during normal or emergency conditions. It must supply food, water, and oxygen, provide for personal hygiene, and remove wastes and contaminants. Finally, the system must control temperatures and heat transfers through utilization of available energy and rejection of excess heat. A basic assumption is that data from other completed space programs will be available for future utilization.

The objective of this Functional Program Element (FPE) is to provide critical information of human environmental requirements, the design criteria for LSPS, and the technology that will enable men to perform future space missions effectively and in safety. The information will be provided through the following goals:

a. Investigation of the basic chemical and physical phenomena, and their occurrence and rates of occurrence in gravity-sensitive elements of future LSPS components and subsystems.

b. Evaluation of advanced component, subsystem, and system performance, reliability, verification, and fit in the space environment.

c. Investigation of man-system and system-vehicle interfaces and demonstration of man's ability to accomplish operation, maintenance, and repair.

6.2 PHYSICAL DESCRIPTION

This FPE is comprised of a test facility to accommodate a number of hardware test specimens. The test specimens may be components, assemblies, or subsystems and are in two categories, namely: a) specimens which are operated experimentally in the test facility while corresponding primary equipment in the space vehicle life support system remains operating; and b) specimens which are operated experimentally and fully replace the corresponding function in the space vehicle. An example of the first category is a 3-man CO_2 collector which is operated experimentally in a 12-man space station while the primary CO_2 removal unit operates at a 9-man rate instead of its usual 12-man rate. An example of the second category is an experimental zero-g shower, which is used by the entire crew in place of the primary bathing facility. Test specimens in this latter category may be installed in locations as determined by

supporting subsystems and other criteria, and not necessarily contiguous to other Life Sciences FPEs. The LSPS test facility, illustrated conceptually in Figure 6-1, consists of the Life Support Subsystems Test Unit plus other equipment for gas analysis, microbiology analysis, airlock/EVA support, biomedical measurements, data management, and maintenance.

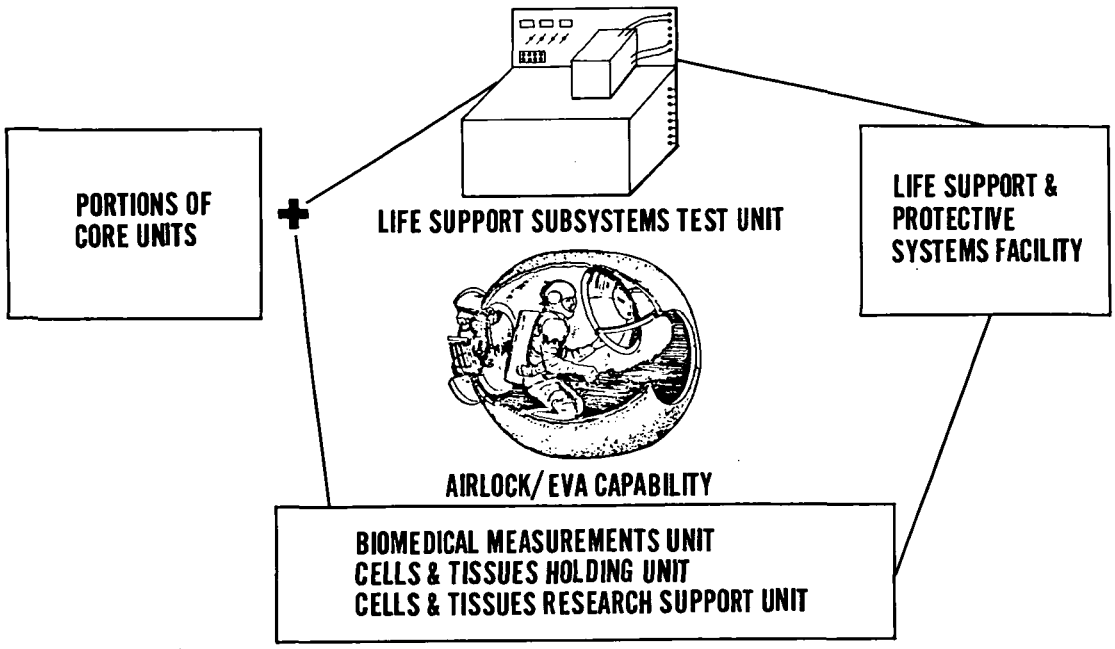


Figure 6-1. Life Sciences Life Support and Protective Systems

6.2.1 LIFE SUPPORT SUBSYSTEMS TEST UNIT. This unit provides utilities, controls, and instrumentation which are common to life support experiments. It will accept for experimental operation at least one test specimen package, which may have additional controls and instrumentation that are experiment-peculiar.

6.2.1.1 Functional Capability. The unit will provide connections from the test specimen to utilities including electrical power, pressurant gas, purge gas, process gases, vacuum, and heat transport fluid supply and return. Manual operating capability will include on-off controls and flow modulation of gases and heat transport fluid. It will have zero-g restraints for the test specimen and for experiment operating personnel, and will be capable of operation also in one-g or fractional-g.

Built-in measurements capability will include transducers and signal conditioners for electrical power parameters and for flow, pressures and temperatures of the heat transport fluid and gases. The unit will provide capability for manual selection and

visual readout of the foregoing, plus a number of experiment-peculiar measurements from the test specimen package. Additional capabilities will include adjustable local lighting, storage, a work bench, and FPE-peculiar tools. Some of the test specimens will process toxic gases and other materials which may involve some biological hazard. Therefore, a shroud will be provided to enclose the unit during such tests. The shroud will be mechanically vented to contaminant-removal units of the space vehicle, or to experiment-peculiar contaminant-removal units within the test specimen package.

6.2.1.2 Description. The Life Support Subsystem Test Unit concept is illustrated in Figure 6-2. It consists basically of a bench and panel with fittings, controls, and instruments as previously stated. The test specimen package is attached to the bench and connected to the utilities, control, and measurements facilities. The Life Support Subsystem Test Unit is connected with the Life Sciences Experiment Support Unit, and in some cases it will have connections also with the space station subsystems.

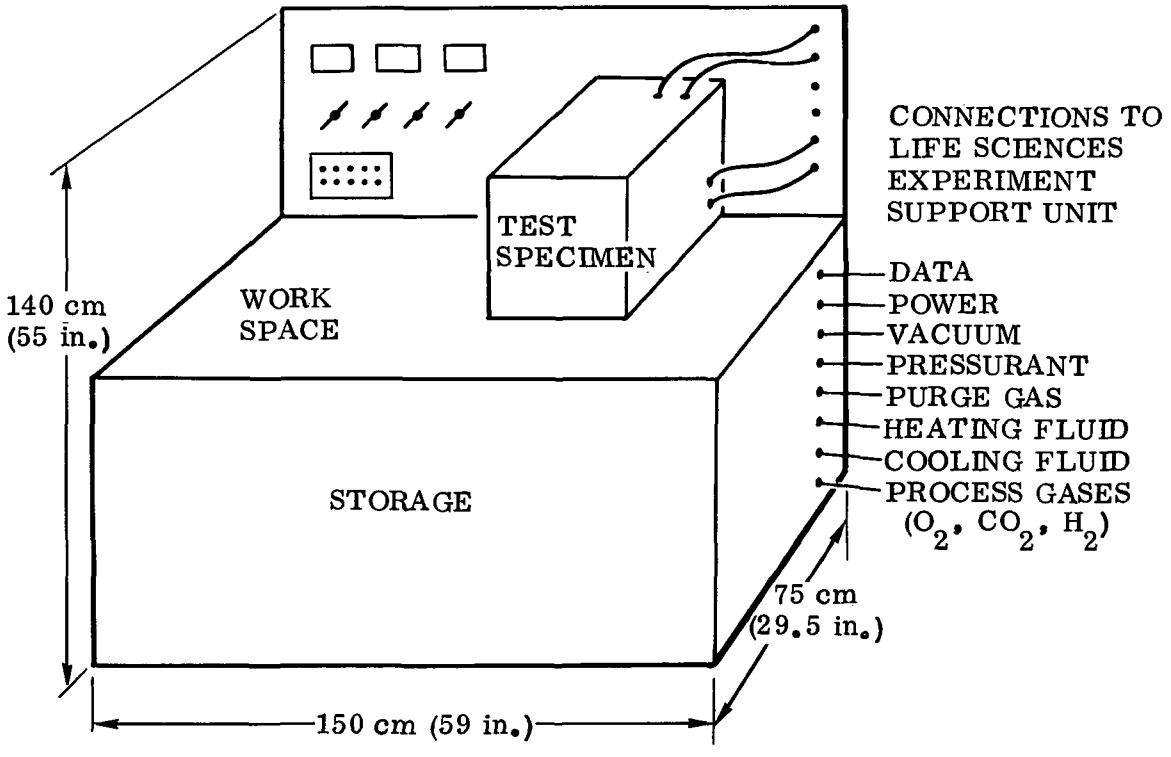


Figure 6-2. Life Support Subsystem Test Unit

The following performance specification applies to the Life Support Subsystem Test Unit:

a. Electrical Power: Type and quality the same as space vehicle supply to the primary life support system. Capacity $\geq$ 1000 watts.

b. Pressurant Gas: Dry gaseous N_2, with pressure adjustable 100 to 1000 kN/m^2 gage (14 to 150 psig) ±2%, and flow capacity ≥ 5 g/sec (40 lb/hr).

c. Oxygen: Dry gaseous O_2, with pressure adjustable 100 to 1000 kN/m^2 gage (14 to 140 psig) ±2%, and flow capacity ≥ 1 g/sec (8 lb/hr).

d. Purge Gas: Same as pressurant gas.

e. Heat Transport Fluid: Type and temperatures the same as space vehicle supply to the primary life support system. Flow capacity 0 to 0.1 kg/s at 50 kN/m^2 difference (0 to 750 lb/hr at 7.25 psid).

f. Vacuum: Flow capacity ≥1.5 dm^3/sec at 0.1 N/m^2 (3 cfm at 0.75 μm Hg).

g. Shroud Purge: Cabin air to contaminant removal unit(s). Flow capacity ≥1 dm^3/sec (2 cfm).

6.2.2 OTHER EQUIPMENT. The LSPS facility includes other equipment which is shared with other FPEs. These equipment units are:

Equipment Unit	Location	Reference Section
Visual Records and Microscopy Unit	CORE	B.1.1
Data Management Unit	CORE	B.1.2
Life Sciences Experiment Support Unit	CORE	B.1.3
Preparation, Preservation and Retrieval Unit	CORE	B.1.4
Biochemical/Biophysical Analysis Unit	CORE	B.1.5
Maintenance, Repair, and Fabrication Unit	CORE	B.1.6
Airlock/EVA Capability	FPE 7	B.4
Biomedical Measurements Unit	FPE 1	1.2
Cells and Tissues Holding Unit	FPE 4	4.2
Cells and Tissues Research Support Unit	FPE 4	4.2

6.3 EXPERIMENT REQUIREMENTS SUMMARY

See Table 6-1. There are no special requirements for vehicle pointing, orbit altitude, or orbit inclination. All experiments are based on conditions of nominal zero-g and nominal vehicle stabilization.

Table 6-1. Experiment Requirements Summary

EXPERIMENT	MASS (WEIGHT) kg (lb)	VOLUME m^3 (ft^3)	ENVELOPE m (ft)	POWER REQUIREMENTS watts	CREW SKILLS	ENVIRONMENT REQUIREMENTS	EXPERIMENT TIME LIMITS	DATA REQUIREMENTS	PREFLIGHT SUPPORT	POSTFLIGHT SUPPORT	EXPERIMENT PECULIAR REQUIREMENTS
6.4.1 Water Recovery Methods and Components	60 (130)	0.2 (7)		Daily avg 67 Max sust 200 Peak 200	2 11 12	Nominal zero g, nominal atmosphere composition & pressure.	Operate 8 hours/day for 30 days per test specimen. Five test specimens in sequence.	Max rate 10.8 bps. Total 6×10^6 bits per specimen. Film, tape, test samples 14 kg (31 lb) per specimen.		Refrigeration for microbiological samples	
6.4.2 Waste Management Methods and Components	40 (90)	0.3 (10)		Daily avg 2 Max sust 50 Peak 50	2 11 12	Same as 6.4.1	Experiment activity one hour/day for 30 days per specimen unit. Continuous operation of some components. Four test specimens in sequence	Max rate 10.2 bps. Total 1.5×10^7 bits per specimen. Film, tape, test samples 10 kg (20 lb) per specimen.		Refrigeration for samples.	
6.4.3 Advanced Cooling System Methods and Components	55 (120)	4.0 (140)		Daily avg 201 Max sust 225 Peak 225	11 12	Same as 6.4.1	Operate 0.5 hour/day for 90 days per test specimen. Continuous operation of some components. Three test specimens in sequence.	Max rate 3.6 bps. Total 2.8×10^7 bits per specimen. Film, tape 4 kg (9 lb) per specimen.			
6.4.4 Zero-Gravity Whole-Body Shower	125 (275)	1.4 (50)		Daily avg 25 Max sust 300 Peak 300	2 11 12	Same as 6.4.1	Experiment activity one hour/day for 30 days.	Max rate 5.9 bps. Total 1.4×10^4 bits. Film, tape 5 kg (10 lb).			
6.4.5 Advanced Two-Gas Atmosphere Supply and Control Subsystem	7 (15)	0.03 (1)		Daily avg 0.5 Max sust 10 Peak 10	11 12 22	Same as 6.4.1	Experiment activity one hour/day for 30 days per specimen unit. Continuous operation of some components. Four test specimens in sequence.	Max rate 7.8 bps. Total 1.3×10^7 bits per specimen. Film, tape 5 kg (10 lb) per specimen.			
6.4.6 Atmosphere Supply Methods and Components	145 (320)	0.2 (7)		Daily avg 1 Max sust 25 Peak 25	11 12 22	Same as 6.4.1	Experiment activity one hour/day for 30 to 270 days per test specimen. Continuous operation of some components. Three test specimens in sequence.	Max rate 7.9 bps. Max total 2×10^8 bits per specimen. Film, tape 5 kg (10 lb) per specimen.	LO_2 and LN_2 storage and transfer facilities.		
6.4.7 Oxygen Regeneration Methods and Components	40 (90)	0.1 (4)		Daily avg 25 Max sust 600 Peak 600	11 12 22	Same as 6.4.1	Experiment activity one hour/day for 30 to 450 days per specimen. Continuous operation of some components. Five test specimens in sequence.	Max rate 6.5 bps. Total 2.6×10^8 bits maximum per specimen. Film, tape 10 kg (20 lb) per specimen.			

Table 6-1. Experiment Requirements Summary (Continued)

EXPERIMENT	MASS (WEIGHT) kg	(lb)	VOLUME m^3	(ft^3)	ENVELOPE m	(ft)	POWER REQUIREMENTS watts		CREW SKILLS	ENVIRONMENT REQUIREMENTS	EXPERIMENT TIME LIMITS	DATA REQUIREMENTS	PREFLIGHT SUPPORT	POSTFLIGHT SUPPORT	EXPERIMENT PECULIAR REQUIREMENTS
6.4.8 Carbon Dioxide Collection Methods and Components	30	(70)	0.3	(10)			Daily avg Max sust Peak	150 160 160	11 12 22	Same as 6.4.1	Experiment activity 0.5 hour/day for 30 days per test specimen. Continuous operation of some components. Four test specimens in sequence.	Max rate 6.4 bps. Total 1.7×10^7 bits per specimen. Film, 5 kg (10 lb) per specimen.			
6.4.9 Advanced Trace Contaminant Control & Monitoring Subsystem	15	(35)	0.1	(4)			Daily avg Max sust Peak	100 150 150	11 12 22	Same as 6.4.1	Experiment activity 0.5 hour/day for 90 days per test specimen. Continuous operation of some components. Four test specimens in sequence.	Max rate 10.4 bps. Total 4.5×10^7 bits per specimen. Film, 5 kg (10 lb) per specimen.			
6.4.10 Protective Clothing and Advanced Space Suit Assemblies	15	(35)	0.2	(7)			Daily avg Max sust Peak	25 100 100	11 12	Interior and exterior of spacecraft.	Experiment activity 6.3 hours/day for 30 days per test specimen. Five test specimens in sequence.	Max rate 1.3×10^5 bps. Total 7×10^9 bits per specimen. TV 0.1 hr/day. Film, tape 20 kg (45 lb).			
6.4.11 EVA Suit and Biopack	25	(55)	0.4	(14)			Daily avg Max sust Peak	25 100 100	11 12	Interior and exterior of spacecraft.	Experiment activity 6.3 hours/day for 30 days per test specimen. Five test specimens in sequence.	Max rate 1.3×10^5 bps. Total 8.4×10^9 bits per specimen. TV 0.1 hr/day. Film, tape 20 kg (45 lb) per specimen.	Refrigeration for food.	Refrigeration for microbiological samples.	
6.4.12 Food Storage, Preparation, and Feeding Methods	65	(145)	0.3	(10)			Daily avg Max sust Peak	20 200 200	11 12 2	Same as 6.4.1	Experiment activity 1.5 hours/day for 30 days per test specimen. Continuous operation of some components. Three test specimens in sequence.	Max rate 9 bps. Total 3×10^8 bits per specimen. Film, tape 10 kg (20 lb) per test specimen			

6.4 EXPERIMENT PROGRAM

The life support and protective systems research program is comprised of a variety of experiments. Twelve representative experiments are described in detail. These selected representative experiments provide experiment support requirements and other spacecraft and mission impacts to a level ample to characterize the requisite Life Support and Protective Systems Research Facility. Table 6-1 and the subsequent paragraphs provide the representative experiments which scope the experiment program.

6.4.1 WATER RECOVERY METHODS AND COMPONENTS

6.4.1.1 Scientific or Technical Objectives. This experiment is intended to verify the operation, maintenance, fault isolation, repair, and sterilization of candidate water recovery systems and components under in-orbit conditions.

6.4.1.2 Description. Specimen water recovery units may include those for recovering usable water from humidity condensate, wash water, urine, feces, food wastes, etc., and may be based on such processes as air evaporation, vapor compression, electrodialysis, reverse osmosis, and multifiltration.

The system will be connected to the utilities, controls, and measurement facilities of the Life Support Subsystem Test Unit. Wastes will be diverted daily from the appropriate spacecraft systems into the candidate system accumulators at a nominal three-man input level unless another input rate, compatible with the subsystem test unit, is justified because of the characteristics of the particular process. Water from the wastes will be reclaimed on an 8-hour/day basis over a 30-day evaluation period.

Physical measurements and product water quality indicators will be selectively monitored by the crew and periodic recordings will be entered in the digital data system. Conductivity meters may be included for indicating process quality or for functional control of some candidate systems and are considered to be experiment-peculiar.

Observations of test equipment maintenance activities and product water purity tests will be made for evaluation of performance characteristics, reliability, maintainability, and product water quality.

6.4.1.3 Observation/Measurement Program. Pressures, temperatures, dewpoints, flow rates, power, liquid and gas leakage, and product water quality observations will require digital data collection at a maximum rate of 10.8 bps.

Voice recordings, still photos, and motion pictures will be taken as required to augment documentation of setup, operation, maintenance, and repair activities. This should involve a maximum of 10 still photos, 300 minutes of voice tape, and 100 minutes of 16 mm film or video tape equivalent per 30-day period.

6.4.1.4 Interface, Support, and Performance Requirements. The crew will perform and document installation, operation, and removal of specimen systems. Operation will include routine maintenance tasks, product water quality tests, and unscheduled repairs. Crew support requirements are summarized in Table 6-2; facility support requirements are summarized in Table 6-3.

Table 6-2. Crew Support Requirements Summary (Water Recovery)

EXPERIMENT EVENT	CREW TASK			CREW		CREW CONSTRAINTS
	TASK DESCRIPTION	FREQUENCY	DURATION	NO.	SKILL	
Equipment Preparation	Receive specimen unit, unpack, check, and connect to utilities, controls, and measurement facilities of the Subsystem Test Unit.	Once per test unit (five units assumed).	7 hours	2	Mech. Engr. & Electromech. Technician.	
Equipment Checkout	Check interfaces, turn equipment on, and check operation of specimen unit, facility equipment, controls, and data system.	Once per test unit.	1 hour	2	Mech. Engr. & Electromech. Technician.	Performed before start of experiment operations.
Experiment Operation and Monitoring	Load and start specimen unit; monitor operations; collect samples; and maintain test log. Stop and secure unit.	Daily for 30 days per test unit.	8 hours	2	Mech. Engr. (1 hr), Electromech. Engr. (2 hrs.)	
	Activate chemical and microbial analysis equipment; conduct lab tests; prepare and store samples; and maintain test log.	Daily for 30 days per test unit.	1 hour	1	Microbiol. Technician.	
Corrective Maintenance	Make equipment repairs necessary for continued testing.	Unscheduled	As required	1 to 3	As required.	
Experiment Termination	Remove and package specimen unit for return with samples and documentation.	Once per test unit.	6 hours	2	Mech. Engr. & Electromech. Technician	Complete by 1st logistic return after experiment termination.

Table 6-3. Facility Support Requirements Summary

Experiment Specimens	
Weight (heaviest), kg (lb)	60 (130)
Volume (largest), m^3 (ft^3)	0.2 (7)
Probable Number	5
Digital Data	
Maximum Rate, bps	10.8
Total, bits per specimen	6×10^6
Electrical Power	
Daily Average, watts AC	67
Maximum Sustained, watts AC	200
Peak, watts AC	200
Thermal Control	
Heat Rejection, watts	Same as electrical power

Digital data totaling 6×10^6 bits per experiment specimen will be recorded and transmitted or returned with the collected microbiological water samples, audio recording tape, photographic film, and water recovery equipment via Shuttle to Earth.

The average daily electrical power requirement will be 67 watts and the maximum sustained and peak powers will be 200 watts. Purge and pressurant gases, vacuum, and heat rejection requirements will vary greatly depending upon the type of process used. Total heat rejection is approximately equal to the electrical power input. Estimated maximum purge and pressurant gas usage is 2 kg (5 lb) per 30-day operation of a specimen unit.

The candidate water recovery systems will operate in the normal pressure, temperature, and zero-g environment of the space vehicle and will not be affected by orbit altitude, inclination, magnetic field, etc. Starting and stopping torques will impose negligible forces on the vehicle.

Prelaunch and return requirements involve packaging for structural survival of acceleration and deceleration forces and for contamination control. Refrigeration for microbiological samples is required on return.

The weight and size of the largest specimen system is estimated at 60 kg (130 lb) and 0.2 m^3 (7 ft^3).

6.4.1.5 Potential Role of Man. The spacecraft crew provides the biological and hygienic waste liquids to be processed in the specimen units. The experiment setup, operation, maintenance, repair, and product water quality determination roles will require the skills of a mechanical engineer, electromechanical technician, microbiological technician, and chemical technician.

6.4.1.6 Available Background Data.

a. Space Marketing Intelligence - National Multipurpose Space Station (NMSS) Experimental Listing. Published by Space Station Study Office, National Aeronautics and Space Administration, Manned Spacecraft Center, Houston, Texas, 17 December 1964.

b. Mars Landing and Reconnaissance Mission Environmental Control and Life Support System Study, Vol. 3 Systems Study (Contract No. NAS9-1701), 1964.

c. Requirements Study for a Biotechnology Laboratory for Manned Earth Orbiting Missions, NASA Report NASA-CR-1408, Volume I, dated August 1969.

d. Requirements Study for a Biotechnology Laboratory for Manned Earth Orbiting Missions, NASA Report NASA-CR-1409, Volume II, dated August 1969.

e. Experiment Program for Extended Earth Orbital Missions (Volume 2), Revision No. 1 to the Experiment Program for Manned Orbital Workshop, September 1969.

6.4.2 WASTE MANAGEMENT METHODS AND COMPONENTS

6.4.2.1 Scientific or Technical Objectives. This experiment is intended to verify the operation, maintenance, fault isolation, repair, and sterilization techniques of candidate waste management systems and components under in-orbit conditions.

6.4.2.2 Description. Specimen waste management units provide for collection and transport of urine and the collection, processing, and storage of feces, sanitary supplies, and food wastes with or without reclamation of by-product gases, water, or

solids. Processing concepts may include dehydration, biological decomposition, or pyrolytic dissociation.

The system will be connected to the utilities, controls, and measurement facilities of the Life Support Subsystem Test Unit. Daily waste input will be provided by the crew at a nominal three-man input level. Where water is to be reclaimed, it will be separated by the waste unit and transferred to the spacecraft water recovery system for processing and purification.

Physical measurements and contaminant level monitors will be selectively checked by the crew and periodic recordings will be entered in the digital data system. Observations concerning test equipment maintenance activities, contaminant control procedures, and esthetics of waste collection, processing, and transport functions will be recorded for system evaluations.

6.4.2.3 Observation/Measurement Program. Pressure, temperature, flow rate, power, product condition, and contaminant monitoring will require digital data collection at a maximum rate of 10.2 bps. Voice recordings, still photos, and motion pictures will be taken as required to augment documentation of setup, operation, maintenance, and repair activities. This could involve 10 still photos, 150 minutes of voice tape, and 60 minutes of 16 mm film or video tape equivalent per 30-day period.

6.4.2.4 Interface, Support, and Performance Requirements. The crew will perform and document installation, operation, and removal of specimen hardware. Operation will include routine maintenance tasks, waste and residue condition checks, contaminant control observation, and unscheduled repairs. Crew support requirements are summarized in Table 6-4 and facility support requirements are summarized in Table 6-5.

Digital data totaling 1.5×10^7 bits per experiment specimen will be recorded and transmitted or returned with the collected microbiological samples, audio recording tape, film, and waste management unit via Shuttle to Earth.

The average daily electrical power requirement will be 2 watts and the maximum sustained and peak powers will be 50 watts. Estimated maximum purge and pressurant gas usage is 2 kg (4 lb) per 30-day operation of a specimen unit. Vacuum may be required for some units. Total heat rejection should be of the same order as electrical power input.

The waste management units will operate in the normal pressure, temperature, and gravity environment of the space vehicle and will not be affected by orbit altitude, inclination, magnetic field, etc. Perturbing forces on the vehicle will be negligible.

Table 6-4. Crew Support Requirements Summary (Waste Management)

EXPERIMENT EVENT	CREW TASK			CREW		CREW CONSTRAINTS
	TASK DESCRIPTION	FREQUENCY	DURATION	NUMBER	SKILL	
Equipment Preparation	Receive specimen unit, unpack, check, and connect to utilities, controls, and measurement facilities of the Subsystem Test Unit.	Once per test unit	7 hours	2	Mech. Engr. & Electromech. Technician	
Equipment Checkout	Check interfaces. Turn equipment on and check operation of specimen unit, facility equipment, controls, and data system.	Once per test unit	1 hour	2	Mech. Engr. & Electromech. Technician	Performed before start of experiment operations.
Experiment Operation and Monitoring	Load specimen unit; monitor operation; collect samples; and maintain test log.	Daily for 30 days per test unit	1 hour (24-hr oper.)	2	Mech. Engr. (1/2 hr); Electromech. Tech.(1/2 hr)	
	Activate chemical and microbial analysis equipment; conduct lab tests; prepare and store samples and maintain test log.	Daily for 30 days per test unit	1 hour	1	Microbiological Technician	
Corrective Maintenance	Make equipment repairs necessary for continued operation.	Unscheduled	As required	1 to 3	As required	
Experiment Termination	Remove and package specimen unit for return with samples and documentation.	Once per test unit	6 hours	2	Mech. Engr. & Electromech. Technician	Complete by first logistic return after experiment termination.

Table 6-5. Facility Support Requirements Summary

Experiment Specimen	
Weight (heaviest), kg (lb)	40 (90)
Volume (largest), m^3 (ft^3)	0.3 (10)
Probable Number	4
Digital Data	
Maximum Rate, bps	10.2
Total, bits per specimen	1.5×10^7
Electrical Power	
Daily Average, watts AC	2
Maximum Sustained, watts AC	50
Peak, watts AC	50
Thermal Control	
Heat Rejection, watts	Same as electrical power

Prelaunch and return requirements involve packaging for structural survival of acceleration and deceleration forces and for contamination control. Refrigeration for microbiological samples is required upon return.

The weight and size of the largest specimen is estimated at 40 kg (90 lb) and 0.3 m^3 (10 ft^3).

6.4.2.5 Potential Role of Man. The spacecraft crew provides the wastes to be collected and processed in the specimen hardware. The experiment setup, operation, maintenance, repair, and waste and residue condition determination roles will require the skills of a mechanical engineer, electromechanical technician, microbiological technician, and chemical technician.

6.4.2.6 Available Background Data

a. Life Support Systems for Space Flight of Extended Time Periods, Convair division of General Dynamics, NASA-CR-614, November 1966.

b. N. Belasco and D. Perry, Waste Management and Personal Hygiene for Extended Spacecraft Missions, NASA Manned Spacecraft Center, Houston, Texas, April 1964.

c. Requirements Study for a Biotechnology Laboratory for Manned Earth Orbiting Missions, NASA-CR-1408, Vol. I, August 1969.

d. Requirements Study for a Biotechnology Laboratory for Manned Earth Orbiting Missions, NASA-CR-1409, Vol. II, August 1969.

e. Experiment Program for Extended Earth Orbital Missions (Volume 2), dated 1 September 1969, Revision No. 1 to the Experiment Programs for Manned Orbital Workshop.

6.4.3 ADVANCED COOLING SYSTEM METHODS AND COMPONENTS

6.4.3.1 Scientific or Technical Objectives. This experiment is intended to verify the operation, maintenance, fault isolation, and repair techniques of candidate advanced cooling systems and components under in-orbit conditions.

6.4.3.2 Description. Cooling systems are required to collect waste heat from spacecraft atmosphere, EVA units, electronic equipment, oxygen regeneration units, and cold storage areas and to dissipate this heat to outer space. Cooling methods may require heat pipes, radiators, heat exchangers, boilers, vapor cycles, absorption cycles, and cryogenic systems.

The hardware specimen system or component will be connected to the utilities, controls, and measurement facilities of the Life Support Subsystem Test Unit. In most cases, simulated heat loads will be required and heat will be dissipated through the appropriate spacecraft systems.

Thermodynamic data will be entered into the digital data system and observations concerning specimen equipment installation, maintenance and repair activities will be recorded for evaluation of performance, reliability, maintainability, and repairability.

6.4.3.3 Observation/Measurement Program. Pressure, temperature, flow rate, humidity, and power monitoring will require digital data collection at a maximum rate of 3.6 bps. Voice recordings, still photos, and motion pictures will be taken as required to augment documentation of installation, operation, maintenance, and repair activities. This may total 5 still photos, 60 minutes of voice tape, and 40 minutes of 16 mm film or video tape equivalent per 90-day period.

6.4.3.4 Interface, Support, and Performance Requirements. The crew will perform and document installation, operation, and removal of specimen systems. Operation will include a daily equipment check, and unscheduled repairs as required. Crew support requirements are summarized in Table 6-6 and facility support requirements in Table 6-7.

Table 6-6. Crew Support Requirements Summary (Adv. Cooling Systems)

EXPERIMENT EVENT	CREW TASK			CREW		CREW CONSTRAINTS
	TASK DESCRIPTION	FREQUENCY	DURATION	NO.	SKILL	
Equipment Preparation	Receive specimen unit, unpack, check, and connect to utilities, controls, and measurement facilities of Subsystem Test Unit.	Once per test unit (three units assumed)	7 hrs.	2	Mech.Engr. & Electromech. Technician	
Equipment Checkout	Check interfaces. Turn equipment on and check operation of specimen unit, facility equipment, controls, and data system.	Once per test unit	1 hr.	2	Mech. Engr.& Electromech. Technician	Performed as start of experiment operations.
Experiment Operation and Monitoring	Monitor operation and maintain test log.	Daily for 90 days per test unit	0.1 hr. (24-hr. oper.)	1	Mech.Engr. to check once per day	
Corrective Maintenance	Make equipment adjustments and repairs necessary for continued operation.	Unscheduled	As req'd	1 or 2	As required	
Experiment Termination	Remove and package specimen for return with documentation.	Once per test unit	6 hrs.	2	Mech.Engr. & Electromech. Technician	Complete by 1st logistic return after experiment termination.

Table 6-7. Facility Support Requirements Summary

Experiment Specimen	
Weight (heaviest), kg (lb)	55 (120)
Volume (largest) m^3 (ft^3)	4 (140)
Probable Number	3
Digital Data	
Maximum Rate, bps	3.6
Total, bits per specimen	2.8×10^7
Electrical Power	
Daily Average, watts AC	200
Maximum Sustained, watts AC	225
Peak, watts AC	225
Thermal Control	
Heat Rejection, watts	Same as electrical power

Digital data totaling 2.8×10^7 bits per experiment will be recorded and transmitted or returned with tape, film, notes, and specimen system via Shuttle to Earth.

The average daily electrical power requirement will be 1 watt and the maximum sustained and peak powers will be 25 watts, exclusive of simulated heat loading. Total heat rejection should be of the same order as electrical power input plus simulated heat loading. Maximum simulated heat loading will be 200 watts. Estimated maximum purge and pressurant gas usage is 1 kg (2.2 lb) per test specimen.

The advanced cooling systems will operate in the normal pressure, temperature, and gravity environment of the space vehicle and will not be affected by orbit altitude, inclination, magnetic field, etc. Perturbing forces on the vehicle will be negligible.

Prelaunch and return requirements are limited to packaging for structural survival of acceleration and deceleration forces. The weight and size of the largest specimen system is estimated at 55 kg (120 lb) and 4 m^3 (140 ft^3).

6.4.3.5 Potential Role of Man. The experiment setup, operation, maintenance, repair, and documentation will require the skills of a mechanical engineer and electromechanical technician.

6.4.3.6 Available Background Data

a. R.S. Osborne, R.W. Johnson, and W.C. Thompson, Experiments for an Engineering Technology Satellite, National Aeronautics and Space Administration, Langley Research Center, Virginia, 23 April 1965.

b. Temperature Control Systems for Space Vehicles, Parts I and II, North American Aviation, Inc. Report ASD-TDR-62-493, 1962-1963.

c. Requirements Study for a Biotechnology Laboratory for Manned Earth Orbiting Missions, NASA-CR-1408, Volume I, August 1969.

d. Requirements Study for a Biotechnology Laboratory for Manned Earth Orbiting Missions, NASA-CR-1409, Volume II, August 1969.

e. Experiment Program for Extended Earth Orbital Missions (Volume 2), dated 1 September 1969, Revision No. 1 to the Experiment Programs for Manned Orbital Workshop.

6.4.4 ZERO-GRAVITY WHOLE-BODY SHOWER

6.4.4.1 Scientific or Technical Objectives. This experiment is intended to demonstrate the operability, maintainability, and cleansing effectiveness of a whole-body shower under in-orbit conditions.

6.4.4.2 Description. The experiment specimen consists of a stall with crew restraint, water spray, air stream, and water collection and air blower system for water control and removal. Spray rate, temperature, and air flow are controlled by the subject crewman.

The specimen unit will be connected to the utilities and measurement facilities of the Life Support Subsystem Test Unit. Waste shower water will be recovered by transfer to the spacecraft water management subsystem. The spacecraft atmosphere control subsystem will be required to remove the shower air heat and evaporated water.

Physical and microbiological measurements will be entered in the digital data system. Crew debriefing remarks and test engineer observations concerning equipment installation, maintenance, and performance will be recorded for evaluation of system effectivity and maintainability.

6.4.4.3 Observation/Measurement Program. Water and airflow rates, temperatures, pressures and microbial condition monitoring will require digital data collection at a maximum rate of 5.9 bps. Voice recordings, photographs, and motion pictures will be taken to augment documentation of installation, operation, and maintenance activities. This may involve 5 still photos, 120 minutes of voice tape, and 60 minutes of 16 mm film or video tape equivalent for the test period.

6.4.4.4 Interface, Support, and Performance Requirements. The crew will perform and document installation, operation, and maintenance of the specimen system. Operation will include three 8-minute showers of individual crew members each day under the direction of the test engineer. At the end of the 30-day test period, the specimen will be removed from the subsystem test unit and will either be integrated with the spacecraft systems or be packaged for return to Earth. Crew support requirements are summarized in Table 6-8 and facility support requirements in Table 6-9.

Table 6-8. Crew Support Requirements Summary (Shower)

EXPERIMENT EVENT	CREW TASK			CREW		CREW CONSTRAINTS
	TASK DESCRIPTION	FREQUENCY	DURATION	NO.	SKILL	
Equipment Preparation	Receive specimen unit, unpack, check, and connect to utilities, controls, and measurement facilities of the Subsystem Test Unit.	Once	10 hrs.	2	Mech.Engr. & Electromech. Technician	
Equipment Checkout	Activate shower and check operation and monitoring and sampling equipment.	Once	30 min.	2	Mech.Engr. & Microbiol. Technician	Performed before initial manned use.
Experiment Operation and Monitoring	Document activities while subject takes shower; take microbial samples; and debrief test subject.	3 times per day for 30 days	8 min. per shower	2	Test Subject & Mech.Engr.	
Experiment Data Evaluation	Perform and review microbial analysis; correlate with operational data.	Daily	30 min.	2	Microbiol. Tech. & Mech. Engr.	
Corrective Maintenance	Make equipment adjustments and repairs necessary for continued operation.	Unscheduled	As required	1 or 2	As required	
Experiment Termination	Remove and package specimen for return with documentation.*	Once per test unit	6 hrs.	2	Mech.Engr. & Electromech. Technician	Complete by 1st logistic return after experiment termination.
	*Optionally, the unit may be designated operational and be connected to spacecraft utilities.					

Table 6-9. Facility Support Requirements Summary

Experiment Specimen	
Weight, kg (lb)	125 (275)
Volume, m^3 (ft^3)	1.4 (50)
Number	1
Digital Data	
Maximum Rate, bps	5.9
Total bits per specimen	1.4×10^4
Electrical Power	
Daily Average, watts AC	25
Maximum Sustained, watts AC	300
Peak, watts AC	300
Thermal Control	
Heat Rejection, watts	Same as electrical power

Digital data totaling 1.4×10^4 bits will be recorded and transmitted or returned with tape, film, and notes via Shuttle to Earth.

The average daily electrical power requirement will be 25 watts and the maximum sustained and peak powers will be 300 watts. Total heat rejection should be of the same order as electrical power input. Estimated maximum purge and pressurant gas usage is 1 kg (2.2 lb).

The whole-body shower will operate in the normal pressure, temperature, and gravity environment of the space vehicle and will not be affected by orbit altitude, inclination, magnetic field, etc. Perturbing forces on the vehicle will be negligible. Prelaunch and return requirements are limited to packaging for structural survival of acceleration and deceleration forces. The weight and size of the largest specimen system is estimated at 125 kg (275 lb) and 1.4 m^3 (50 ft^3).

6.4.4.5 Potential Role of Man. The experiment setup, operation, maintenance, and documentation will require the skills of a mechanical engineer, electromechanical technician, and microbiological technician. The spacecraft crew members will serve as subjects.

6.4.4.6 Available Background Data

a. Requirements Study for a Biotechnology Laboratory for Manned Earth-Orbiting Missions, NASA-CR-1408, Volume I, August 1969.

b. Requirements Study for a Biotechnology Laboratory for Manned Earth-Orbiting Missions, NASA-CR-1409, Volume II, August 1969.

c. Experiment Program for Extended Earth Orbital Missions (Volume 2), dated 1 September 1969, Revision No. 1 to the Experiment Program for Manned Orbital Workshop.

6.4.5 ADVANCED TWO-GAS ATMOSPHERE SUPPLY AND CONTROL SUBSYSTEM

6.4.5.1 Scientific or Technical Objectives. The objective of this experiment is to compare, evaluate and verify the performance of the most promising concepts of

two-gas atmosphere supply and control systems which have been proven in a manned space cabin simulator or other man-rating tests.

6.4.5.2 Description. This experiment will evaluate and verify various methods of supplying and controlling a two-gas environment for manned occupancy. A test specimen two-gas control will be installed in the Life Support Subsystem Test Unit to serve as the primary mode of space vehicle gas supply and control. The space vehicle baseline system will be shut down but will serve as a redundant or backup mode during the test. The baseline system should be designed to permit operation of the test specimen without interference. The test specimen may perform the function of one or more pieces of the baseline system and will be operated for a sufficient period of time to obtain complete data on performance, maintainability, reliability and long-life stability. One concept that has shown promise in Earth tests is a multigas mass spectrometer sensor and control. This concept will not only replace the baseline control system but also part of the gas monitoring system. This device, as well as others, may be tested in conjunction with an atmosphere supply and storage system.

Physical measurements and partial pressures of the atmosphere constituents will be selectively monitored by the crew and by automatic warning devices. Periodic recordings will be entered in the digital data system. Observations of test specimen maintenance activities will be made for evaluation of reliability and maintainability.

6.4.5.3 Observation/Measurement Program. Measurements are made for experiment data and to provide safety of the crew from undesirable concentrations of the gases being measured, for assurance of proper gas ratios of the breathing mixture, and for identification of design problems inherent in the equipment under test. Major measurements include pressure, temperature, gas composition, flow rates, power level, and time. The maximum digital data rate is 7.8 bps. Voice recordings, still photos, and motion pictures will be taken as required to augment documentation of setup, operation, maintenance, and repair activities. This will involve a maximum of 10 still photos, 60 minutes of voice tape, and 60 minutes of 16 mm film or video tape equivalent per 30-day period.

6.4.5.4 Interface, Support, and Performance Requirements. The crew will perform and document installation, operation, and removal of the test specimens. Operation will include routine maintenance tasks, atmosphere composition monitoring, and unscheduled repairs. Crew support requirements are summarized in Table 6-10 and facility support requirements are summarized in Table 6-11.

Digital data totaling 1.3×10^7 bits per experiment specimen will be recorded and transmitted or returned with the audio recording tape, photographic film, and any written notes or log. The test specimen may be returned via Shuttle, or it may be installed in the space vehicle as a replacement for the baseline unit.

Table 6-10. Crew Support Requirements Summary (Adv. Two-Gas Atmos.)

EXPERIMENT EVENT	CREW TASK			CREW		CREW CONSTRAINTS
	TASK DESCRIPTION	FREQUENCY	DURATION	NO.	SKILL	
Equipment Preparation	Receive specimen unit, unpack, check, and connect to utilities, controls, and measurement facilities of the Subsystem Test Unit.	Once per test unit (4 units assumed)	8 hrs.	2	Mech.Engr. & Electromech. Technician	
Equipment Checkout	Check interfaces, turn equipment on, and check operation of specimen unit, facility equipment, controls, and data system.	Once per test unit	0.5 hr.	2	Mech.Engr. & Chemical Technician	Performed before start of experiment operations.
Experiment Operation and Monitoring	Start specimen unit; monitor operations; collect samples; and maintain test log. Stop and secure unit.	Operate continuously for 30 days. Monitor daily.	1 hr.	1	Chemical Technician or Mech. Engr.	Crew may monitor ad lib.
Corrective Maintenance	Make equipment repairs necessary for continued testing.	Unscheduled	As required	1 to 3	As required	
Experiment Termination	Remove and package specimen unit for return with samples and documentation.	Once per test unit	6 hrs.	2	Mech. Engr. & Electromech. Technician	

Table 6-11. Facility Support Requirements Summary

Experiment Specimen	
Weight, kg (lb)	7 (15)
Volume, m^3 (ft^3)	0.03 (1)
Number	4
Digital Data	
Maximum Rate, bps	7.8
Total bits per specimen	1.3×10^7
Electrical Power	
Daily Average, watts AC	0.5
Maximum Sustained, watts AC	10
Peak, watts AC	10
Thermal Control	
Heat Rejection, watts	Same as electrical power

The average daily electrical power requirement will be 0.5 watt and the maximum sustained and peak powers will be 10 watts. Estimated maximum purge gas usage is 0.5 kg (1 lb).

The test specimens will operate in the normal pressure, temperature, and zero-g environment of the space vehicle and will not be affected by orbit altitude, inclination, magnetic field, etc. Prelaunch and return requirements are limited to packaging for structural survival of acceleration and deceleration forces. Perturbing forces and torques on the vehicle by the specimen will be negligible. The weight and size of the largest test specimen is estimated at 7 kg (15 lb) and 0.03 m^3 (1 ft^3).

6.4.5.5 Potential Role of Man. The spacecraft crew lives in the atmosphere and consumes the oxygen being controlled by the test specimen. Experiment setup, operation, maintenance, repair, and atmosphere-composition monitoring will require the skills of a mechanical engineer, an electromechanical technician, and a chemical technician.

6.4.5.6 Available Background Data

a. IBM Experiment Program for Manned Earth Orbital Missions, Volume I, IBM Report No. 65-928-63 (Contract No. NAS1-4667), August 1965.

b. Requirements Study for a Biotechnology Laboratory for Manned Earth-Orbiting Missions, NASA Report NASA-CR-1408, Volume I, dated August 1969.

c. Requirements Study for a Biotechnology Laboratory for Manned Earth-Orbiting Missions, NASA Report NASA-CR-1409, Volume II, dated August 1969.

d. Experiment Program for Extended Earth Orbital Missions (Volume 2), Revision No. 1 to the Experiment Program for Manned Orbital Workshop, September 1969.

6.4.6 ATMOSPHERE SUPPLY METHODS AND COMPONENTS

6.4.6.1 Scientific or Technical Objectives. The objective of this experiment is to compare, evaluate, and verify the performance of different concepts of oxygen and nitrogen storage for normal and emergency functions. Subcritical storage, chemical storage and reliquefaction concepts will be evaluated after they have been proven in manned space cabin simulation or other man-rating tests.

6.4.6.2 Description. This is basically a multiphase experiment to evaluate improvements in lightweight concepts of storing the required atmosphere constituents. Short-duration missions such as Gemini and Apollo used supercritical storage. As mission durations increase and consumption rates decrease (due to use of oxygen reclamation), improved storage techniques are required. These techniques include improved insulations to extend the zero-boiloff time, storage at subcritical conditions with single-phase discharge, and reliquefaction of stored commodities with low power consumption. Another phase of this experiment will be to obtain operational data in space on chemical concepts that can be used to provide emergency supplies of oxygen or small quantities of nitrogen over long periods of time to meet the anticipated low leakage rates of future space vehicles. Each concept, as it is approved for space vehicle test, will be installed to replace the function of one or more pieces of the baseline system hardware. The test hardware will then become the primary mode of atmosphere supply with the baseline system as backup. Various concepts can be tested simultaneously because some are storage techniques as well as supply techniques.

The subcritical portion of this experiment can be accomplished as a piggyback experiment where supercritical or gaseous atmosphere supply is used as the primary system until a subcritical unit is flight qualified. The use of an active refrigeration/reliquefaction system combined with thermal insulation may be necessary to conserve boiloff and minimize weight, volume, and power penalties to the space vehicle. This phase of the experiment could also be used to evaluate the performance for boiloff recovery systems for interplanetary vehicle systems. Chemical sources may be used for applications where long-term storage is a requirement. Applications include emergency

breathing supply, space suit biopacks, and inflation of various devices. This phase will include use of superoxides, chlorate candles, hydrogen peroxide, and nitrogen producing chemicals.

The test specimen will be connected to the utilities, controls, and measurement facilities of the Life Support Subsystem Test Unit. Operation will be at the atmosphere supply rate required by the space vehicle and crew. Physical measurements and atmosphere quality indicators will be selectively monitored by the crew and periodic recordings will be entered in the digital data system. Observations of specimen equipment maintenance activities will be made for evaluation of reliability and maintainability.

6.4.6.3 Observation/Measurement Program. Measurements will be designed to protect the crew from hazardous conditions (high pressure or temperature conditions, and atmospheric contaminants), as well as to evaluate the performance of the system or concept under test. The major measurements to be made include delivery rate (with and without heat input), performance, pressure, temperature, leakage, power level, time, humidity, heat requirements, flow rate, reliability, maintainability, chemical contaminants, contaminant levels, efficiency, and heat transfer rate/heat balance, and will require digital data collection at a maximum rate of 7.9 bps. Voice recordings, still photos, and motion pictures will be taken as required to augment documentation of setup, operation, maintenance, and repair activities. This should involve a maximum of 10 still photos, 60 minutes of voice tape, and 60 minutes of 16 mm film or video tape equivalent per test period of 30 to 270 days.

6.4.6.4 Interface, Support, and Performance Requirements. The crew will perform and document installation, operation, and removal of specimen systems. Operation will include routine maintenance tasks, gas purity tests, and unscheduled repairs. Crew support requirements are summarized in Table 6-12 and facility support requirements are summarized in Table 6-13.

Digital data totaling 2×10^8 bits per experiment specimen will be transmitted or recorded and returned with the audio recording tape, photographic film, and selected test equipment via Shuttle to Earth.

The average daily electrical power requirement will be one watt and the maximum sustained and peak powers will be 25 watts. Purge gases and heat rejection requirements will vary depending upon the type of process used. Total heat rejection is approximately equal to the electrical power input, with corrections for latent heat and heat of reaction. Estimated maximum purge gas usage is 2 kg (4.4 lb) per hardware specimen tested.

The candidate atmosphere supply systems will operate in the normal pressure, temperature, and zero-g environment of the space vehicle and will not be affected by orbit altitude, inclination, magnetic field, etc. Starting and stopping torques will

Table 6-12. Crew Support Requirements Summary (Atmos. Supply)

EXPERIMENT EVENT	CREW TASK			CREW		CREW CONSTRAINTS
	TASK DESCRIPTION	FREQUENCY	DURATION	NO.	SKILL	
Equipment Preparation	Receive specimen unit, unpack, check, and connect to utilities, controls, and measurement facilities of the Subsystem Test Unit.	Once per test unit	8 hrs.	2	Mech.Engr. & Electromech. Technician	
Equipment Checkout	Check interfaces, turn equipment on, and check operation of specimen unit, facility equipment, controls, and data system.	Once per test unit	0.5 hr.	2	Mech.Engr. & Electromech. Technician	Performed prior to start of experiment operations.
Experiment Operation and Monitoring	Start specimen unit; monitor operations; collect samples; and maintain test log. Stop and secure unit.	Daily. Test runs vary from 30 to 270 days	1 hr.	2	Mech.Engr. & Chemical Technician	
Corrective Maintenance	Make equipment repairs necessary for continued testing.	Unscheduled	As req'd	1 to 3	As required	
Experiment Termination	Remove and package specimen unit for return with samples and documentation.	Once per test unit	8 hrs.	2	Mech.Engr. & Electromech. Technician	Complete by 1st logistic return after experiment completion.

Table 6-13. Facility Support Requirements Summary

Experiment Specimen	
Weight, kg (lb)	145 (320)
Volume, m^3 (ft^3)	0.2 (7)
Number	3
Digital Data	
Maximum Rate, bps	7.9
Total bits per specimen	2×10^8
Electrical Power	
Daily Average, watts AC	1
Maximum Sustained, watts AC	25
Peak, watts AC	25
Thermal Control	
Heat Rejection, watts	~25

impose negligible forces on the vehicle. Prelaunch and return requirements are limited to packaging for structural survival of acceleration and deceleration forces and for contamination control. The weight and size of the largest specimen system is estimated at 145 kg (320 lb) and 0.2 m^3 (7 ft^3).

6.4.6.5 Potential Role of Man. The spacecraft crew will live in the atmosphere and consume the oxygen supplied by the specimen units. The experiment setup, operation, maintenance, repair, and gas-purity-determination roles will require the skills of a mechanical engineer, electromechanical technician, and chemical technician.

6.4.6.6 Available Background Data

a. Experiment Program for One-Year Space Station Mission, Memorandum, George C Marshall Space Flight Center, Huntsville, Alabama, 10 February 1967.

b. Analytical Methods for Space Vehicle Atmospheric Control Processes, Part II, Airesearch Manufacturing Company, Report No. ASD-TDR-61-162, Contract No. AF33(616-8323.

c. Effects of the Reliquefaction System on the Auxiliary Power System Requirements for Interplanetary Missions, Douglas Paper No. DP-3003, 30 November 1964.

d. Requirements Study for a Biotechnology Laboratory for Manned Earth-Orbiting Missions, NASA Report NASA-CR-1408, Volume I, dated August 1969.

e. Requirements Study for a Biotechnology Laboratory for Manned Earth-Orbiting Missions, NASA Report NASA-CR-1409, Volume II, dated August 1969.

f. Experiment Program for Extended Earth Orbital Missions (Volume 2), Revision No. 1 to the Experiment Program for Manned Orbital Workshop, September 1969.

6.4.7 OXYGEN REGENERATION METHODS AND COMPONENTS

6.4.7.1 Scientific or Technical Objectives. The objective of this experiment is to compare, evaluate and verify the performance of different methods of obtaining oxygen from byproducts of human metabolism such as water and carbon dioxide. Tests planned in this experiment will be promising concepts that require flight verification after being satisfactorily evaluated in a space cabin simulator or other manned tests.

6.4.7.2 Description. This experiment will have phased testing of promising concepts for reclaiming oxygen from metabolic byproducts. The use of water for O_2 supply or as part of a closed-cycle oxygen recovery system must be applied to future vehicles. A major problem in the use of electrolysis involves operation in zero-gravity. Many concepts have been proposed, such as a rotating cell, ion exchange membrane, and KOH liquid matrix unit. Various methods are used and proposed for O_2 recovery from CO_2, with the Sabatier and Bosch hydrogeneration reactions being the most common, for the production of water.

The test specimen will be connected to the utilities, controls, and measurement facilities of the Life Support Subsystem Test Unit. Materials to be processed will be diverted from the appropriate spacecraft systems into the candidate system accumulators at a nominal three-man input level unless another input rate, compatible with the subsystem test unit, is justified because of the characteristics of the particular process.

Physical measurements and gas purity indicators will be selectively monitored by the crew and periodic recordings will be entered in the digital data system. Observations of equipment maintenance activities will be made for evaluation of performance characteristics, reliability, and maintainability.

6.4.7.3 Observation/Measurement Program. Measurements are necessary to acquire experimental data and to ensure safety of the crew, performance of the equipment, and minimum interference with other space vehicle tests and systems. The major measurements to be made include temperature, pressure, power level, flow rate, leakage, reliability, maintainability, time, gas composition, performance, chemical contaminants and contaminant levels, and will require digital data collection

at a maximum rate of 6.5 bps. Voice recordings, still photos, and motion pictures will be taken as required to augment documentation of setup, operation, maintenance, and repair activities. This should involve a maximum of 10 still photos, 120 minutes of voice tape, and 120 minutes of 16 mm film or video tape equivalent per test period.

6.4.7.4 Interface, Support, and Performance Requirements. The crew will perform and document installation, operation, and removal of specimen systems. Operation will include routine maintenance tasks, gas purity tests, and unscheduled repairs. Crew support requirements are summarized in Table 6-14 and facility support requirements are summarized in Table 6-15.

Table 6-14. Crew Support Requirements Summary (Oxygen Regeneration)

EXPERIMENT EVENT	CREW TASK			CREW		CREW CONSTRAINTS
	TASK DESCRIPTION	FREQUENCY	DURATION	NO.	SKILL	
Equipment Preparation	Receive specimen unit, unpack, check, and connect to utilities, controls, and measurement facilities of the Subsystem Test Unit.	Once per test unit	8 hrs.	2	Mech.Engr. & Electromech. Technician	
Equipment Checkout	Check interfaces, turn equipment on, and check operation of specimen unit, facility equipment, controls, and data system.	Once per test unit	1 hr.	2	Mech.Engr. & Electromech. Technician	Performed before start of experiment operations.
Experiment Operation and Monitoring	Start specimen unit; monitor operations; collect samples; and maintain test log. Stop and secure unit.	Daily per test unit. Runs vary 30 to 450 days.	1 hr.	2	Mech.Engr. & Chemical Technician	
Corrective Maintenance	Make equipment repairs necessary for continued testing.	Unscheduled	As req'd	1 to 3	As required	
Experiment Termination	Remove and package specimen unit for return with samples and documentation.	Once per test unit	4 hrs.	2	Mech.Engr. & Electromech. Technician	Complete by 1st logistic return after experiment completion.

Table 6-15. Facility Support Requirements Summary

Experiment Specimen	
Weight, kg (lb)	40 (90)
Volume, m^3 (ft^3)	0.1 (4)
Number	5
Digital Data	
Maximum Rate, bps	6.5
Total bits per specimen	2.6×10^8
Electrical Power	
Daily Average, watts AC	25
Maximum Sustained, watts DC	600
Peak, watts DC	600
Thermal Control	
Heat Rejection, watts	TBD (~ 600 w)

Digital data totaling 2.6×10^8 bits per experiment specimen will be recorded and transmitted or returned with the audio recording tape, photographic film, and oxygen recovery equipment via Shuttle to Earth.

The average daily electrical power requirement will be 25 watts and the maximum sustained and peak powers will be 600 watts. Purge and pressurant gases, vacuum, and heat rejection requirements will vary greatly depending upon the type of process used. Total heat rejection is approximately equal to the electrical power input with corrections for dissociation or reaction energy rates.

Estimated maximum purge and pressurant gas usage is 2 kg (5 lb) per 30-day operation of a specimen unit.

The candidate oxygen recovery systems will operate in the normal pressure, temperature, and zero-g environment of the space vehicle and will not be affected by orbit altitude, inclination, magnetic field, etc. Starting and stopping torques will impose negligible forces on the vehicle. Prelaunch and return requirements are limited to packaging for structural survival of acceleration and deceleration forces and for contamination control. The weight and size of the largest specimen system is estimated at 40 kg (90 lb) and 0.1 m^3 (4 ft^3).

6.4.7.5 Potential Role of Man. The spacecraft crew provides the CO_2 and/or water to be processed in the specimen units, and consumes the oxygen produced. The experiment setup, operation, maintenance, repair, and product quality determination roles will require the skills of a mechanical engineer, electromechanical technician, and chemical technician.

6.4.7.6 Available Background Data

a. Report on the Development of the Manned Orbital Research Laboratory (MORL); System Utilization Potential, Analysis of Space Related Objectives, Douglas Report No. SM-48808, September 1965.

b. NASA Experiments Descriptions for Extended Apollo Earth Orbit Flights, 15 March 1965.

c. Descriptive Titles of Experiments Selected by Langley Research Center, 15 November 1965.

d. Requirements Study for a Biotechnology Laboratory for Manned Earth-Orbiting Missions, NASA Report NASA-CR-1408, Volume I, dated August 1969.

e. Requirements Study for a Biotechnology Laboratory for Manned Earth-Orbiting Missions, NASA Report NASA-CR-1409, Volume II, dated August 1969.

f. Experiment Program for Extended Orbital Missions (Volume 2), Revision No. 1 to the Experiment Program for Manned Orbital Workshop, September 1969.

6.4.8 CARBON DIOXIDE COLLECTION METHODS AND COMPONENTS

6.4.8.1 Scientific or Technical Objectives. The objective of this experiment is to develop, through extension of the technology available, CO_2 removal and concentration subsystems with improved reliability and maintenance characteristics. Efforts are also underway to extend absorption technology, develop water-tolerant absorption media, and improve regeneration capability with waste heat while reducing system weight and power requirements. Long-term mission systems are being sought which will have inherently longer life and higher reliability than current absorption schemes.

6.4.8.2 Description. Manned flights require removal of metabolically produced CO from the gaseous environments. In longer missions, the requirements exists for concentrating the CO for subsequent reduction and oxygen recovery. This experiment will evaluate and verify techniques that have shown promise during terrestrial testing.

Candidate techniques include regenerative molecular sieves, carbonation cells, and other advanced CO_2 removal methods that minimize weight, volume, power, and thermal penalties to the space vehicle. The molecular-sieve CO_2 removal system cyclically uses thermal energy and vacuum to regenerate the sieve beds and to help transfer, with the assistance of a pump, the CO_2 in the sieves to the O_2 recovery system. Additionally, the silica gel beds are regenerated by the heat from the thermal control system. The beds are also cooled after regeneration by the thermal control system. This test will evaluate waste heat and other heat sources for regenerating the molecular-sieve beds.

The test specimen CO_2 collector will be connected to the utilities, controls, and measurement facilities of the Life Support Subsystem Test Unit. The test specimen will operate at a nominal three-man level unless another rate, compatible with the subsystem test unit, is justified because of the characteristics of the particular process. Operation will be continuous over a 30-day evaluation period. Physical measurements and gas purity will be selectively monitored by the crew and periodic recordings will be entered in the digital data system. Observations of test specimen maintenance activities will be made for evaluation of performance characteristics, reliability, and maintainability.

6.4.8.3 Observation/Measurement Program. Measurements are required to obtain the performance characteristics of the equipment under test and to provide warning of hazardous concentrations of CO_2 or desorbed contaminants. The major measurements and observations include flow rate, efficiency, pressures, temperatures, power levels, time, leakage, gas consumption, contaminants, and heat requirement, and will require digital data collection at a maximum rate of 6.4 bps. Voice recordings, still photos, and motion pictures will be taken as required to augment documentation of setup, operation, maintenance, and repair activities. This should involve a maximum of 10 still photos, 60 minutes of voice tape, and 60 minutes of 16 mm film or video tape equivalent per 30-day period.

6.4.8.4 Interface, Support, and Performance Requirements. The crew will perform and document installation, operation, and removal of specimen systems. Operation will include routine maintenance tasks, product CO_2 purity tests, and unscheduled repairs. Crew support requirements are summarized in Table 6-16 and facility support requirements are summarized in Table 6-17.

Digital data totaling 1.7×10^7 bits per experiment specimen will be recorded and transmitted or returned with the audio recording tape, photographic film, and CO_2 collection equipment via Shuttle to Earth.

Table 6-16. Crew Support Requirements Summary (Carbon Dioxide Collect.)

EXPERIMENT EVENT	CREW TASK			CREW		CREW CONSTRAINTS
	TASK DESCRIPTION	FREQUENCY	DURATION	NO.	SKILL	
Equipment Preparation	Receive specimen unit, unpack, check, and connect to utilities, controls, and measurement facilities of the Subsystem Test Unit.	Once per test unit	8 hrs.	2	Mech.Engr. & Electromech. Technician	
Equipment Checkout	Check interfaces, turn equipment on, and check operation of specimen unit, facility equipment, controls, and data system.	Once per test unit	1 hr.	3	Mech.Engr., Electromech. Tech., & Chem. Technician	Performed before start of experiment operations.
Experiment Operation and Monitoring	Start specimen unit; monitor operations; collect samples; and maintain test log. Stop and secure unit.	Daily for 30 days per test unit	0.5 hr.		Mech.Engr. & Chem. Engr.	
Corrective Maintenance	Make equipment repairs necessary for continued testing.	Unscheduled	As req'd	1 to 3	As required	
Experiment Termination	Remove and package specimen unit for return with samples and documentation.	Once per test unit	4 hrs.	2	Mech.Engr. & Electromech. Technician	Complete by 1st logistic return after experiment completion.

Table 6-17. Facility Support Requirements Summary

Experiment Specimen	
Weight (heaviest), kg (lb)	30 (70)
Volume (largest), m^3 (ft^3)	0.3 (10)
Probable Number	4
Digital Data	
Maximum Rate, bps	6.4
Total bits per specimen	1.7×10^7
Electrical Power	
Daily Average, watts AC	150
Maximum Sustained, watts AC	160
Peak, watts AC	160
Thermal Control	
Heat Rejection, watts	~ 1000

The average daily electrical power requirement will be 150 watts and the maximum sustained and peak powers will be 160 watts. Purge gases, vacuum, and heat rejection requirements will vary depending upon the type of process used. Total heat rejection is approximately equal to the electrical power input plus nonelectrical heat supplied. Estimated maximum purge gas usage is 1 kg (2 lb) per 30-day operation of a specimen unit. The candidate CO_2 collection systems will operate in the normal pressure, temperature, and zero-g environment of the space vehicle and will not be affected by orbit altitude, inclination, magnetic field, etc. Starting and stopping torques will impose negligible forces on the vehicle. Prelaunch and return requirements are limited to packaging for structural survival of acceleration and deceleration forces and for contamination control. The weight and size of the largest specimen system is estimated at 30 kg (70 lb) and 0.3 m^3 (10 ft^3).

6.4.8.5 Potential Role of Man. The spacecraft crew provides the CO_2 to the atmosphere for collection by the specimen units. The experiment setup, operation,

maintenance, repair, and product CO_2 purity determination roles will require the skills of a mechanical engineer, electromechanical technician, and chemical technician.

6.4.8.6 Available Background Data.

a. Analytical Methods for Space Vehicle Atmospheric Control Processes, Part II, Airesearch Manufacturing Company Report No. ASD-TDR-61-162 (Contract No. AF 33 616-8323).

b. Life Support Systems for Space Flight of Extended Time Periods, General Dynamics Report No. 64-262-3 (Contract No. NAS9-2934).

c. A.D. Babinsky, et al., Carbon Dioxide Concentration System, NASA Report No. CR-72086, 30 July 1966.

d. T.C. Secord and M.S. Bonura, Life Support Data from Sixty-Two Days of Testing in a Space Cabin Simulator, Douglas Paper No. DP-3397, October 1965.

e. Final Technical Report, Study of Zero Gravity Capabilities of Life Support System Components and Processes, Convair division of General Dynamics, Report No. GDC-DBD67-004, February 1968.

f. Space Marketing Intelligence, National Multipurpose Space Station (NMSS) Experimental Listing, Published by Space Station Study Office, National Aeronautics and Space Administration, Manned Spacecraft Center, Houston, Texas, 17 December 1964.

g. Requirements Study for a Biotechnology Laboratory for Manned Earth-Orbiting Missions, NASA Report NASA-CR-1408, Volume I, dated August 1969.

h. Requirements Study for a Biotechnology Laboratory for Manned Earth-Orbiting Missions, NASA Report NASA-CR-1408, Volume I, dated August 1969.

i. Experiment Program for Extended Earth Orbital Missions (Volume 2), Revision No. 1 to the Experiment Program for Manned Orbital Workshop, September 1969.

6.4.9 ADVANCED TRACE-CONTAMINANT CONTROL AND MONITORING SUBSYSTEM

6.4.9.1 Scientific or Technical Objectives. The objective of this experiment is to provide technology for the control and/or elimination of trace contaminants in spacecraft atmospheres. Also, this experiment is to verify catalytic beds in conjunction with particulate filters and chemsorbent beds, and onboard monitoring and gas analysis devices.

6.4.9.2 Description. This experiment will evaluate and verify various methods of controlling and monitoring trace contaminants, both physical and biological, within a closed environment to ensure or provide a habitable closed or semiclosed environment. The equipment of this experiment will be operated in parallel with the life

support and protective system baseline. The baseline will serve as a control on the advanced technology concept. If the baseline system lacks the capability to serve as a control (that is, if the new concept is more sensitive to a greater variety of contaminants), then the verification of the new equipment must be performed with the chemical and microbial laboratory equipment. This experiment will be conducted for as long as is desirable to validate performance of the test equipment. However, in order to get sufficient information for reliability and maintainability, it is recommended that the equipment operate a minimum of 90 days.

The test specimen will be connected to the utilities, controls, and measurement facilities of the Life Support Subsystem Test Unit. Process flow will be at a nominal three-man input level unless another input rate, compatible with the subsystem test unit, is justified because of the characteristics of the particular process. Physical measurements and contaminant measurements will be selectively monitored by the crew and periodic recordings will be entered in the digital data system. Observations of test specimen maintenance activities will be made for evaluation of performance characteristics, reliability, and maintainability.

6.4.9.3 Observation/Measurement Program. Measurements will be designed to provide safety for the crew from undesirable physical and biological contaminants, identification of design problems inherent in the equipment under test, and identification of performance of the equipment. The major measurements to be made include temperature, pressure, efficiency, flow rate, gas composition, humidity, time, leakage, power level, performance, reliability, maintainability, chemical and biological contaminants, and will require digital data collection at a maximum rate of 10.4 bps. Voice recordings, still photos, and motion pictures will be taken as required to augment documentation of setup, operation, maintenance, and repair activities. This should involve a maximum of 10 still photos, 60 minutes of voice tape, and 60 minutes of 16 mm film or video tape equivalent per 90-day period.

6.4.9.4 Interface, Support, and Performance Requirements. The crew will perform and document installation, operation, and removal of specimen systems. Operation will include routine maintenance tasks, contaminant measurements, and unscheduled repairs. Crew support requirements are summarized in Table 6-18 and facility support requirements are summarized in Table 6-19.

Digital data totaling 4.5×10^7 bits per experiment specimen will be recorded and transmitted or returned with the audio recording tape, photographic film, and water recovery equipment via Shuttle to Earth.

The average daily electrical power requirement will be 100 watts and the maximum sustained and peak powers will be 150 watts. Purge gases, vacuum, and heat rejection requirements will vary depending upon the type of process used. Total heat

Table 6-18. Crew Support Requirements Summary (Adv. Trace-Contaminant)

EXPERIMENT EVENT	CREW TASK			CREW		CREW CONSTRAINTS
	TASK DESCRIPTION	FREQUENCY	DURATION	NO.	SKILL	
Equipment Preparation	Receive specimen unit, unpack, check, and connect to utilities, controls, and measurement facilities of the Subsystem Test Unit.	Once per test unit	8 hrs.	2	Mech.Engr. & Electromech. Technician	
Equipment Checkout	Check interfaces, turn equipment on, and check operation of specimen unit, facility equipment, controls, and data system.	Once per test unit	0.5 hr.	3	Mech.Engr., Electromech. Technician, Chem. Technician	Performed before start of experiment operations.
Experiment Operation and Monitoring	Start specimen unit; monitor operations; collect samples; and maintain test log. Stop and secure unit.	Daily for 90 days per test unit	0.5 hr.	2	Mech.Engr. & Microbiol. Technician	
Corrective Maintenance	Make equipment repairs necessary for continued testing.	Unscheduled	As req'd	1 to 3	As required	
Experiment Termination	Remove and package specimen unit for return with samples and documentation.	Once per test unit	4 hrs.	2	Mech.Engr. & Electromech. Technician	Complete by 1st logistic return after experiment completion.

Table 6-19. Facility Support Requirements Summary

Experiment Specimen	
Weight (heaviest), kg (lb)	15 (35)
Volume (largest), m^3 (ft^3)	0.1 (4)
Probable Number	4
Digital Data	
Maximum Rate, bps	10.4
Total bits per specimen	4.5×10^7
Electrical Power	
Daily Average, watts AC	100
Maximum Sustained, watts AC	150
Peak, watts AC	150
Thermal Control	
Heat Rejection, watts	150

rejection is approximately equal to the electrical power input. Estimated maximum purge gas usage is 1 kg (2 lb) per 90-day operation of a specimen unit.

The candidate contaminant control systems will operate in the normal pressure, temperature, and zero-g environment of the space vehicle and will not be affected by orbit altitude, inclination, magnetic field, etc. Starting and stopping torques will impose negligible forces on the vehicle. Prelaunch and return requirements are limited to packaging for structural survival of acceleration and deceleration forces and for contamination control. The weight and size of the largest specimen system is estimated at 15 kg (35 lb) and 0.1 m^3 (4 ft^3).

6.4.9.5 Potential Role of Man. The spacecraft crew lives in the atmosphere in which contaminants are controlled and provides part of the contaminant "load" to be removed by specimen units. The experiment setup, operation, maintenance, repair, and contaminant measurement roles will require the skills of a mechanical engineer, electromechanical technician, microbiological technician, and chemical technician.

6.4.9.6 Available Background Data

a. Report on the Development of the Manned Orbital Research Laboratory (MORL): System Utilization Potential, Analysis of Space Related Objectives, Douglas Report No. SM-48808, September 1965.

b. Descriptive Titles of Experiments Selected by Langley Research Center, 15 November 1963.

c. Requirements Study for a Biotechnology Laboratory for Manned Earth-Orbiting Missions, NASA Report NASA-CR-1408, Volume I, August 1969.

d. Requirements Study for a Biotechnology Laboratory for Manned Earth-Orbiting Missions, NASA Report NASA-CR-1409, Volume II, August 1969.

e. Experiment Program for Extended Earth-Orbital Missions (Volume 2), Revision No. 1 to the Experiment Program for Manned Orbital Workshop, September 1969.

6.4.10 PROTECTIVE CLOTHING AND ADVANCED SPACE SUIT ASSEMBLIES

6.4.10.1 Scientific and Technical Objectives. The objectives of this experiment are to verify the operation and maintenance of space suit components and systems designed to protect, sustain, and support man against environmental extremes which may occur in all phases of extravehicular or intravehicular orbital or surface operational manned space flight missions. This will be accomplished by utilization of spacesuit systems as test specimens and space life support systems for test support.

6.4.10.2 Description. Various concepts of both intravehicular and extravehicular apparel will be tested in the environment for which the suit was designed. Tests will include constant-wear garments, cooled undergarments, and space suits. The suits and/or subassemblies will be evaluated in environments of various thermal, micrometeoroid, and vacuum conditions. Suit environmental control will be by PLSS or umbilical to the space vehicle system. As a safety feature, some of the apparel may be tested with a manikin in lieu of a crew member, particularly in the more hazardous environments to which the suit will be subjected. The suits or assemblies will be donned, doffed, and worn for intervals of time sufficient to evaluate and verify wear rates, abrasion resistance, insulation potential, mobility, and comfort to the wearer. Emergency conditions will be simulated to minimize the effect on the space vehicle and the number of crew members affected by the experiment.

6.4.10.3 Observation/Measurement Program. The evaluation and verification of different pieces of protective clothing and space suits and assemblies will require numerous measurements, motion picture documentation, and subjective evaluations by the personnel participating in the experiment. Measurements taken will be designed to satisfy the testing required of the pieces as well as to ensure safety of the crew members during execution of the test. The major measurements to be made

include comfort criteria, mobility, pressure, temperature, gas composition, power level, flow rate, time, humidity, performance, radiation levels, leakage, and biomedical monitoring, and will require digital data collection at a maximum rate of 1.3×10^5 bps. Voice recordings, still photos, and motion pictures will be taken as required to augment documentation of donning, doffing, mobility tests, maintenance, and repair activities. This should involve a maximum of 20 still photos, 720 minutes of voice tape, and 360 minutes of 16 mm film or video tape equivalent per 30-day period.

6.4.10.4 Interface, Support, and Performance Requirements. The crew will perform and document experiment operation, routine maintenance, and unscheduled repairs. Crew support requirements are summarized in Table 6-20 and facility support requirements are summarized in Table 6-21.

Table 6-20. Crew Support Requirements Summary (Protective Clothing)

EXPERIMENT EVENT	CREW TASK			CREW		CREW CONSTRAINTS
	TASK DESCRIPTION	FREQUENCY	DURATION	NO.	SKILL	
Equipment Preparation	Initial Receive equipment, unpack, check and store constant wear garments and test suits and support equipment.	Once per garment or suit type (2 types of constant wear garments and 3 types of suit sizes assumed)	3 hrs. (6 man-hrs.)	2	Mech. Engr. & Electromech. Technician	
	Suit Assembly Tests Remove and inspect suit; apply sensors to self or manikin; don suit or suit manikin; connect to life support services and/or connect for data monitoring (IMS).	Daily for 30 days per test type (3 assumed)	1 hr. (1 - 2 man-hrs)	2	Mech.Engr., Any (Subject)	Duration in man-hours depends on whether or not man is suited or manikin is used.
	Constant Wear Garments Remove from storage and don.	Daily for 30 days per type (2 assumed)				Constant wear garment assessment is performed by replacing nominal crew member IVA garments with test garments. Crew time is allocated to that associated with personal time for dressing.
Initialization and Verification	Suit Assembly Tests Checkout suit operations and/or cooling garment performance, data return, communications and data acquisition.	Daily for 30 days	15 min. (0.5 man-hr)	2	Mech.Engr. & Any (Subject)	Performed each day prior to operations.
	Constant Wear Garments Not applicable.					

Table 6-20. Crew Support Requirements Summary (Protective Clothing), Contd

EXPERIMENT EVENT	CREW TASK			CREW		CREW CONSTRAINTS
	TASK DESCRIPTION	FREQUENCY	DURATION	NO.	SKILL	
Experiment Activation Operations, Deactivation	Suit Assembly Tests Initiate test protocol, monitor data return, perform test sequence, terminate sequence, remove, check and stow suits, debrief subject.	Daily for 30 days	6 hrs. (6-12 man-hrs)	1 - 2	Mech. Engr., Any (Subject)	See "crew constraints" for preparation.
	Constant Wear Garments Collect wearer subjective data.	Daily for 30 days	5 min. (20 man-min.)	4	Mech. Engr., Any (Subjects)	Assume three crew members wear advanced constant wear garments.
Experiment Data Evaluation	Screen data return and interface with ground re. data return requirements and schedule continuously extension.	Daily for 30 days for each suit assembly or garment	15 min. (15 man-min.)	1	Mech. Engr.	Task can be performed ad lib
Refurbishment	Service suit assemblies as required.	As required	30-60 min. (30-60 man-min.)	1	Mech. Engr.	Task can be performed ad lib.
Component Experiment Termination	Prepare tested suit assembly or garments (unless disposable) and physical data and, when applicable, support equipment for return to ground.	Once per suit assembly/garment type tested)	6 hrs. (6 man-hrs.)	1	Mech. Engr.	Can be performed ad lib at point in time logistics return vehicle is available.

Table 6-21. Facility Support Requirements Summary

Experiment Specimen	
Weight (heaviest), kg (lb)	15 (35)
Volume (largest), m^3 (ft^3)	0.2 (7)
Probable Number	5
Digital Data	
Maximum Rate, bps	1.3×10^5
Total bits per specimen	7×10^9
Electrical Power	
Daily Average, watts AC	25
Max. Sustained, watts AC	100
Peak, watts AC	100
Thermal Control	
Heat Rejection, watts	100

Digital data totaling 7×10^9 bits per experiment specimen will be recorded and transmitted or returned with the audio recording tape, photographic film, and test specimens via Shuttle to Earth.

The average daily electrical power requirement will be 25 watts and the maximum sustained and peak powers will be 100 watts.

Experiment operations will be in vacuum as well as the normal pressure, temperature, and zero-g environment of the space vehicle and will not be affected by orbit altitude, inclination, magnetic field, etc. Forces imposed on the space vehicle will be of the same order as from normal crew activities. Prelaunch and return requirements are limited to packaging test specimens for structural survival of acceleration and deceleration forces.

The weight and size of the largest specimen is estimated at 15 kg (35 lb) and 0.2 m^3 (7 ft^3) and the total for all specimens is 45 kg (100 lb) and 0.6 m^3 (20 ft^3).

6.4.10.5 Potential Role of Man. Two crew members will be required to perform this experiment over the duration of the test. One man will assist during the donning and doffing, operate and monitor the measuring equipment, take movies, and operate the controls during egress and ingress. The second man will perform tests in the garment assemblies. A minimum of 30 tests will be performed on each garment assembly unless the unit fails prior to completing that many tests.

6.4.10.6 Available Background Data.

a. Report on the Development of the Manned Orbital Research Laboratory (MORL): System Utilization Potential, Analysis of Space Related Objectives, Douglas Report No. SM-48808, September 1965.

b. NASA Experiment Descriptions for Extended Apollo Earth Orbit Flights, 15 March 1965.

c. IBM Experiment Program for Manned Earth Orbital Missions, Volume I, IBM Report No. 65-928-63 (Contract No. NAS1-4667), August 1965.

d. Experiment Program for One-Year Space Station Mission, Memorandum, George C. Marshall Space Flight Center, Huntsville, Alabama, 10 February 1967.

e. Requirements Study for a Biotechnology Laboratory for Manned Earth-Orbiting Missions, NASA Report NASA-CR-1408, Volume I, dated August 1969.

f. Requirements Study for a Biotechnology Laboratory for Manned Earth-Orbiting Missions, NASA Report NASA-CR-1409, Volume II, dated August 1969.

g. Experiment Program for Extended Earth Orbital Missions (Volume 2), Revision No. 1 to the Experiment Program for Manned Orbital Workshop, September 1969.

6.4.11 EVA SUIT AND BIOPACK

6.4.11.1 Scientific or Technical Objectives. The objectives of this experiment are to evaluate physical capabilities of a crewman clothed in an experimental spacesuit, and to evaluate and verify the effectiveness and durability of the spacesuit and biopack through a complete spectrum of motions and environments.

6.4.11.2 Description. This experiment will test advanced concepts of EVA suits and biopacks. After the suit has been adequately tested on the ground, it will be delivered to the space laboratory for final verification and qualification. Orbital testing will include all activities that are to be anticipated for a complete mission. The biopack will be tested under basal metabolic rates as well as high stress rates imposed by strenuous activities. Emergency modes will be simulated to validate support and

rescue should the need arise. In some cases, a manikin may be used in place of a crew member. Maintenance, repair, inspection, equipment retrieval, and experiment installation are some of the evaluations that will be accomplished with the suit and biopack. Other test activities are donning and doffing, tether attachment, dexterity, habitability and comfort, which will include some subjective evaluations. Biopacks will be tested for ease of putting on, duration of operation, efficiency of gas utilization, thermal performance, and control of pressure and composition of gas supplied to the suit.

6.4.11.3 Observation/Measurement Program. The evaluation and verification program of different styles, types and configurations of EVA suits and biopacks will require both subjective and quantitative measurements by the experiment operators, by FPE equipment, and by special measurements equipment attached to the man and biopack. The measurements taken will be designed to satisfy the testing required of the test pieces as well as to ensure the safety of crew members participating in the test. The major measurements to be made include humidity, pressure, temperature, flow rate, mobility, gas composition, gas consumption, comfort criteria, power level, time, leakage, performance, contaminant level, metabolic rate, and biomedical condition of participant, and will require digital data collection at a maximum rate of 1.3×10^5 bps. Voice recordings, still photos, and motion pictures will be taken as required to augment documentation of experiment performance, maintenance, and repair activities. This should involve a maximum of 10 still photos, 360 minutes of voice tape, and 360 minutes of 16 mm film or video tape equivalent per 30-day period.

6.4.11.4 Interface, Support, and Performance Requirements. The crew will perform and document experiment operation, routine maintenance, and unscheduled repairs. Crew support requirements are summarized in Table 6-22 and facility support requirements are summarized in Table 6-23.

Digital data totaling 8.4×10^9 bits per experiment specimen will be recorded and transmitted or returned with audio recording tape, photographic film, and test specimens via Shuttle to Earth.

The average daily electrical power requirement will be 25 watts and the maximum sustained and peak powers will be 100 watts. Purge and pressurant gases, vacuum, and heat rejection requirements will vary depending upon the test specimen. Total heat rejection is approximately equal to the electrical power input. Estimated maximum purge and pressurant gas usage is 0.5 kg (1 lb) per 30-day operation of a specimen unit.

Test operations will be in the zero-g environment of the space vehicle and will not be affected by orbit altitude, inclination, magnetic field, etc. Forces imposed on the vehicle by test activities will be of the same order as normal crew activities. Prelaunch and return requirements are limited to packaging test specimens for structural

Table 6-22. Crew Support Requirements Summary (EVA Suit and Biopack)

EXPERIMENT EVENT	CREW TASK			CREW		CREW CONSTRAINTS
	TASK DESCRIPTION	FREQUENCY	DURATION	NO.	SKILL	
Equipment Preparation	Initial Receive equipment, unpack, check and store EVA suits, biopacks, and support equipment.	Once per test specimen (2 types of EVA suit and 3 types of biopack assumed)	3 hrs. (6 man-hrs)	2	Mech.Engr. & Electromech. Technician	
	Suit Assembly Tests Remove and inspect suit; apply sensors to self or manikin; don suit or suit manikin; connect to life support services and/or connect for data monitoring	Daily for 30 days per test type (2 assumed)	1 hr. (1-2 man-hrs)	2	Mech. Engr., Any (Subject)	Duration in man-hours depends on whether or not man is suited or manikin is used.
	Biopack Tests Remove from storage and don Connect for data monitoring	Daily for 30 days per type (3 assumed)				
Initialization and Verification	Suit Assembly Tests Checkout suit operations, communications, and data acquisition.	Daily for 30 days	15 min. (0.5 man-hr)	2	Mech.Engr. & Any (Subject)	Performed each day prior to operations.
	Biopack Tests Check all performance parameters.					
Experiment Activation Operations Deactivation	Suit Assembly Tests Initiate test protocol, monitor data return, perform test sequence, terminate sequence, remove, check and stow suits, debrief subject.	Daily for 30 days	6 hrs. (6-12 man-hrs)	1-2	Mech.Engr., Any (Subject)	Assume at least two subjects in sequence.
	Biopack Tests Perform test sequence. Monitor data return. Collect wearer subjective data.	Daily for 30 days	5 min. (20 man-min.)	4	Mech.Engr., Any (Subjects	
Experiment Data Evaluation	Screen data return and interface with ground re. data return requirements and schedule continuously extension.	Daily for 30 days for each suit assembly or biopack	15 min. (15 man-min.)	1	Mech. Engr.	Task can be performed ad lib.
Refurbishment	Service suit assemblies and biopacks as required.	As required	30-60 min. (30-60 man-min.)	1	Mech.Engr.	Task can be performed ad lib.
Component Experiment Termination	Prepare tested suit assembly or biopack and physical data and, when applicable, support equipment for return to ground.	Once per suit assembly/biopack type tested)	6 hrs. (6 man-hrs.)	1	Mech. Engr.	Can be performed ad lib at point in time logistics return vehicle is available.

Table 6-23. Facility Support Requirements Summary

Experiment Specimen	
Weight (heaviest), kg (lb)	25 (55)
Volume (largest), m^3 (ft^3)	0.4 (14)
Probable Number	5
Digital Data	
Maximum Rate, bps	1.3×10^5
Total bits per specimen	8.4×10^9
Electrical Power	
Daily Average, watts AC	25
Max. Sustained, watts AC	100
Peak, watts AC	100
Thermal Control	
Heat Rejection, watts	100

survival of acceleration and deceleration forces. The weight and size of the largest specimen system is estimated at 25 kg (55 lb) and 0.4 m^3 (14 ft^3)

6.4.11.5 Potential Role of Man. Two crew members will be required to perform this experiment over the duration of the test. One man will assist the test subject as required during various evolutions, operate and monitor the measuring equipment, take movies, and operate the controls during egress and ingress. The second man will perform tests with the suit and his biopack. Approximately halfway through the test program, the men will change jobs. A minimum of 30 tests will be performed on each unit under test unless the unit fails prior to completing that many tests.

6.4.11.6 Available Background Data.

a. Report on the Development of the Manned Orbital Research Laboratory (MORL): System Utilization Potential, Analysis of Space Related Objectives, Douglas Report No. SM-48808, September 1965.

b. Descriptive Titles of Experiments Selected by Langley Research Center, 15 November 1963.

c. Requirements Study for a Biotechnology Laboratory for Manned Earth Orbiting Missions, NASA Report NASA-CR-1408, Volume I, dated August 1969.

d. Requirements Study for a Biotechnology Laboratory for Manned Earth-Orbiting Missions, NASA Report NASA-CR-1409, Volume II, dated August 1969.

e. Experiment Program for Extended Earth Orbital Missions (Volume 2), Revision No. 1 to the Experiment Program for Manned Orbital Workshop, September 1969.

6.4.12 FOOD STORAGE, PREPARATION, AND FEEDING METHODS

6.4.12.1 Scientific or Technical Objectives. Objectives of this experiment are to evaluate and verify food, feeding methods, storage and preparation techniques, and waste handling methods that have been proven in ground-based space cabin simulator tests.

6.4.12.2 Description. Food management for long-duration flights involves food storage, preparation, feeding devices, and residue disposal. Food concepts used on recent flights and in space cabin simulator tests only partly meet requirements of taste, nutrition, long term storage, and simplicity of preparation. This experiment will evaluate, in orbit, those concepts of food management that meet the above requirements. On a rotating basis, all onboard crew members will participate in daily scheduled subjective evaluations of food qualities as to flavor, texture, appearance, and satiety. Foods, packaging, and equipment will be evaluated for ease of preparation and serving, and quantity of residue. These tests will be conducted for a minimum of 30 days for each concept or technique being tested or evaluated. Freeze-dried or possibly frozen food cooked in small microwave ovens may be used. Other possibilities involve foods produced by microbiological and/or chemical systems for prolonged space missions.

The man/food system interface will be further evaluated from the standpoint of crew capabilities in zero-g. The experiment will compare various kinds of foods, food packaging, preparation equipment, serving equipment, and eating devices for qualities of convenience, sanitation, and general user appeal. Time required for pre- and post-meal food management tasks will be measured. Evaluations of sanitation will include microbiological analysis. Observations will be made of test equipment maintenance activities. Crew capabilities and adaptation will be documented in motion pictures.

The experiment will include engineering tests to verify zero-g thermal and fluid behavior in test specimen components for heating, chilling, mixing, or other functions in food storage, preparation, and serving. Such components or subsystems will be connected to the utilities, controls, and measurement facilities of the Life Support Subsystem Test Unit. Operation of test specimens will be at a level sufficient for support of three men unless another level of operation is justified because of characteristics of the particular test specimen or process. Physical measurements will be selectively monitored by the crew and periodic recordings will be entered in the digital data system. Observation of specimen equipment maintenance activities will be made for evaluation of reliability and maintainability.

6.4.12.3 Observation/Measurement Program. The evaluation and verification program of food storage, preparation, feeding methods and food will require subjective comments by crew members participating in the test. Tests of preparation and storage equipment will include measurements of power level, humidity, temperature, pressure, food and water use rate, and waste quantities, and will require digital data collection at a maximum rate of 9 bps. Voice recordings, still photos, and motion pictures will be taken as required to augment documentation of setup, testing, maintenance, and repair activities. This should involve a maximum of 10 still photos, 300 minutes of voice tape, and 100 minutes of 16 mm film or video tape equivalent per 30-day period.

6.4.12.4 Interface, Support, and Performance Requirements. Crew members will perform and document installation, operation, and removal of specimen systems. Operation will include routine maintenance tasks, microbiological tests, and unscheduled repairs. Crew support requirements are summarized in Table 6-24 and facility support requirements are summarized in Table 6-25.

Table 6-24. Crew Support Requirements Summary (Food Storage)

EXPERIMENT EVENT	CREW TASK			CREW		CREW CONSTRAINTS
	TASK DESCRIPTION	FREQUENCY	DURATION	NO.	SKILL	
Equipment Preparation	Receive, unpack check and install equipment; connect to support services & monitor/control interface	Once per test unit/concept (3 assumed)	8 hours (16 man-hours)	2	Mech Engr - Electromech Tech	
Initiation and Verification	Activate equipment and check operational and data return	Once per test unit/concept (3 assumed)	30 Min. (30 man-minutes)	1	Mech Engr	Performed any time prior to operations
Experiment Activation, Operations and Deactivation	Perform daily food preparation, etc., via test unit; check (monitor) operational data, take subjective data from subject crew emembers	Daily for 30 days per test unit	30 Min. (1 man-hour)	2 Minimum	Mech Engr-Any (Subjects)	Two subjects utilize test unit for daily food preparation, etc etc. Time is not charged to experiment. Experiment time represents time for Test Engr to take subjective data from each crew member (15 minutes each) and to perform brief monitoring of operating parameters
	Perform microbial analysis of food and feeding equipment and blomed analysis of subjects (nutritional)	Daily for 30 days per test unit	1.5 Hrs (1.5 man-hrs)	1	Microbio Tech	
Experiment Data Evaluation	Correlate operational data with microbal/nutritional data; screen and compress for return to ground, interface with P.I.	Daily for 30 days per test unit	30 Min (60 man-minutes)	2	Mech Engr - Microbio Tech	
Corrective Maintenance	Make equipment repairs necessary for continued testing	Unscheduled	As required	1-3	As required	
Component Experiment Termination	Prepare experiment equipment, physical data for return to ground	Once per test unit	6 Hrs (12 man-hours)	2	Mech Engr - Electromech Tech	Perform any time prior to availability of return logistics vehicle

Digital data totaling 3×10^8 bits per experiment specimen will be recorded and transmitted or returned with the collected microbiological samples, audio recording tape, photographic film, and test specimens via Shuttle to Earth.

The average daily electrical power requirement will be 20 watts and the maximum sustained and peak powers will be 200 watts. Purge and pressurant gases, vacuum, and heat rejection requirements will vary depending upon type of process used. Total heat rejection is approximately equal to the electrical power input. Estimated maximum purge and pressurant gas usage is 1 kg (2 lb) per 30-day operation of a specimen unit.

Food management test specimens will operate in the normal pressure, temperature, and zero-g environment of the space vehicle and will not be affected by orbit altitude,

Table 6-25. Facility Support Requirements Summary

Experiment Specimens	
Weight (heaviest), kg (lb)	65 (145)
Volume (largest), m^3 (ft^3)	0.3 (10)
Probable Number	3
Digital Data	
Maximum Rate, bps	9
Total, bits per specimen	3×10^8
Electrical Power	
Daily average, watts AC	20
Max. sustained, watts AC	200
Peak, watts AC	200
Thermal Control	
Heat Rejection, watts	Same as electrical power

inclination, magnetic field, etc. Starting and stopping torques will impose negligible forces on the vehicle. Prelaunch and return requirements involve packaging for structural survival of acceleration and deceleration forces and for contamination control. Prelaunch refrigeration of food is required. Refrigeration for microbiological samples is required on return. Weight and size of the largest specimen system is estimated at 65 kg (14.5 lb) and 0.3 m^3 (10 ft^3).

6.4.12.5 Potential Role of Man. All crew members of the space vehicle will participate in this experiment. Each concept, technique or piece of equipment will be tested over a 30-day (minimum) period of time to ensure that personnel have time to become fully acquainted with the process, taste, operation, etc., of whatever is being evaluated.

The spacecraft crew consumes the specimen food which is processed in the specimen units. The experiment setup, operation, maintenance, repair, and microbiological determination roles will require skills of a mechanical engineer, electromechanical technician, and microbiological technician.

6.4.12.6 Available Background Data.

a. IBM Experiment Program for Manned Earth Orbital Missions, Volume I, IBM Report No. 65-928-63 (Contract No. NASI-4667), August 1965.

b. Space Marketing Intelligence-National Multipurpose Space Station (NMSS) Experimental Listing. Published by Space Station Study Office, National Aeronautics and Space Administration, Manned Spacecraft Center, Houston, Texas, 17 December 1964.

c. Requirements Study for a Biotechnology Laboratory for Manned Earth-Orbiting Missions, NASA Report NASA-CR-1408, Volume I, dated August 1969.

d. Requirements Study for A Biotechnology Laboratory for Manned Earth-Orbiting Missions, NASA Report NASA-CR-1409, Volume II, dated August 1969.

e. Experiment Program for Extended Earth Orbital Missions (Volume 2), Revision No. 1 to the Experiment Program for Manned Orbital Workshop, September 1969.

6.5 FPE INTERFACE, SUPPORT, AND PERFORMANCE REQUIREMENTS

This FPE requires the nominal space vehicle pressurized environment, nominal zero-g, and nominal stabilization. There are no special requirements as to ephemeris, pointing, Earth's magnetic field, orbit altitude, or orbit inclination. Experiments 6.4.10 and 6.4.11 involve activities with pressure suits and biopacks which require use of an airlock for access to unpressurized space. In all experiments, forces and torques produced will be of the same order as those incident to normal crew activities. Tests involving electrolysis in Experiment 6.4.7 will produce magnetic fields corresponding to about 30 amperes DC. Crew participation as experiment operators is required daily for all experiments. The crew members also interface with the FPE as test subjects, as consumers of metabolic input materials and as sources of metabolic wastes. All experiments include documentation by motion picture and by audio tape.

The summary data presented in Table 6-26 represents, in the best judgment of NASA scientists, the overall facility and experimental requirements to accomplish a realistic experimental program, and is based on some projection of the state of the art. The rationale for selection of the summary parameters is in some instances arbitrary but has as a basis the total NASA experience and knowledge gained from prior flight and experiment definition and integration programs. The basis for each data entry is given in the notes.

Table 6-26. Life Support and Protective Systems FPE Summary Data

Weight, kg (lb)	3339 (7360)	Note 1
Volume, m^3 (ft^3)	25 (883)	Note 1
Power, watts	3655	Note 2
Crew Skills	2, 11, 12, 22	
Data Rate, bps	3.3×10^5	Note 2
Logistics Up, 30-day average, kg (lb)	101 (223)	Note 3
Logistics Down, 30-day average, kg (lb)		
1st 2 years	76 (168)	Note 4
3rd year on	91 (201)	Note 5
Pointing and Stabilization	NA	
Orbit Altitude and Inclination	NA	
Unique Environment Requirements	EVA	

Note 1: CORE units + FPE units + two logistic cycles of expendables.
Note 2: 40% of CORE units total + 75% of FPE units total = normal load.
Note 3: 1% of FPE units + 110% of expendables per 30 days research.
Note 4: 75% of logistics up.
Note 5: 90% of logistics up.

6.6 POTENTIAL MODE OF OPERATION

Since all experiments of this FPE are designed for daily participation by the crew, the mode of operation must be compatible with such participation. The LSPS facility may be integral with Space Station or in a manned experiment module. Most of the experiments specify a 30-day test run per hardware specimen, which is compatible with a limited on-orbit stay time. The exceptions are: Experiment 6.4.6, which specifies test runs to 270 days to verify time-dependent performance of long-duration cryogenic storage; Experiment 6.4.7, which specifies test runs to 450 days to determine time-dependent degradation of performance in certain oxygen recovery components; and Experiment 6.4.9, which specifies test runs to 90 days to determine time-dependent changes in levels of trace contaminants in the cabin atmosphere. These exceptions require extended on-orbit stay time.

In summary, nine of the twelve experiments can be accommodated by Mode A, limited on-orbit stay time as with Space Shuttle, provided a 30-day duration is available. None of the experiments can be satisfactorily accommodated by Mode B, extended on-orbit stay time, unmanned, with periodic revisits by Space Shuttle. All of the experiments can be accommodated by Mode C, extended on-orbit stay time with Space Station, and this is the preferred mode.

6.7 POTENTIAL ROLE OF MAN

As stated in Section 6.5, the crew participates as experimenters, as test subjects, as consumers of metabolic input materials produced by processes of the experimental hardware, and as sources of metabolic wastes to be processed by the experimental hardware. Prior to each experiment they will receive, unpack, set up, and check out the test specimen. At experiment termination they will dismantle, pack, and dispatch the test specimen for return by Shuttle. Required skills are mechanical engineer, electromechanical technician, microbiological technician, and chemical technician. It may be feasible to train a single crewman as a microbiological and a chemical technician for the requirements of this FPE.

6.8 SCHEDULES

Figure 6-3 is a representative schedule for any experiment of this FPE. There is no relationship requiring a particular experiment to precede or follow any other, except for limitations in support by the crew and facility. Such limitations will probably not allow all 12 experiments to be in operation simultaneously. Within each experiment, there are relationships such that test specimens will be operated sequentially. The schedule shown provides for up to five test specimens per experiment.

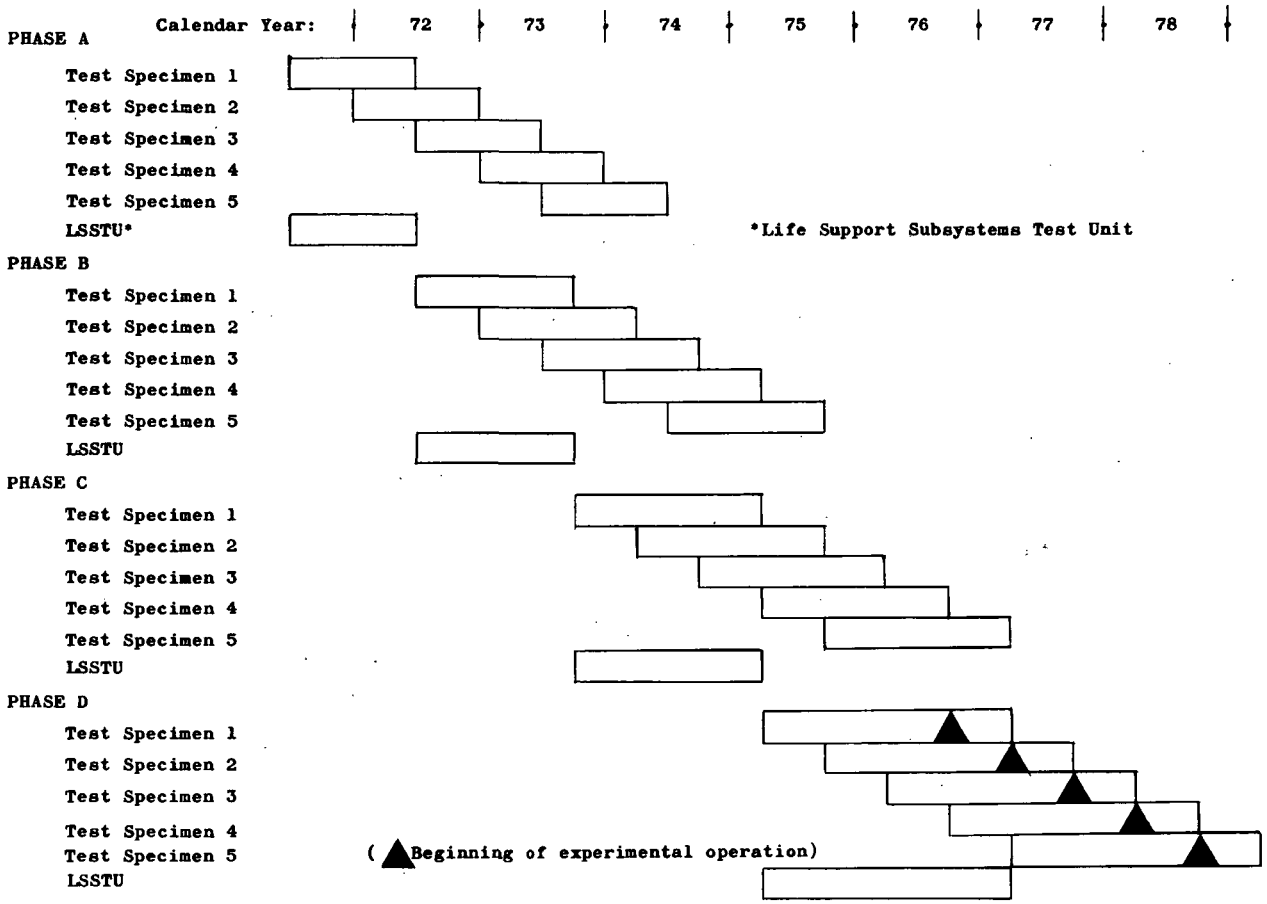


Figure 6-3. Schedule

6.9 PRELAUNCH SUPPORT REQUIREMENTS AND GSE

The FPE requires facilities for prelaunch transfer of LO_2 and LN_2 into experimental tankage. There are requirements for postflight refrigeration of microbiological samples.

6.10 SAFETY ANALYSIS

Table 6-27 lists potential hazards and safety precautions to be observed.

6.11 AVAILABLE BACKGROUND DATA

a. June 1970 Blue Book.

b. General Electric, Space Systems Organization, EL-103, Revision C, Experiment Data Book, Volume 1, prepared for North American Rockwell Corporation, Space Division, 12 June 1970.

c. Martin Marietta Corporation, Denver Division, Space Station Phase B Definition Study, Experiments and Accommodations, Analysis of Operations, ED-3421-8III-001, 27 February 1970.

d. General Dynamics, Convair Division, Experiment Module Concept Study, Final Report, Report No. GDC-DAA70-004, Contract NAS8-25051, October 1970

Table 6-27. Safety Analysis

EXPERIMENT	POTENTIAL HAZARD	SAFETY PRECAUTIONS
All	Electrical shock.	Design to preclude crew exposure to live conductors in normal operation. Provide grounding of all chassis and frames. Incorporate interlocks and discharge devices to permit maintenance and servicing. Restoration of power shall require deliberate action by crew member.
	Cuts and abrasions.	Design equipment without sharp edges and corners. Design for maintenance and servicing so that crew does not have to exert high forces and torques.
	Breakage of fragile equipment.	Design equipment for adequate strength. Train crew in safety requirements where some fragility is unavoidable.
6.4.1	Microbiological contamination. Burns.	Design for containment. Provide microbiological monitoring in flight. Design adequate thermal insulation.
6.4.2	Same as 6.4.1.	Same as 6.4.1.
6.4.3	Burns. Toxic liquids. Toxic gases.	Design adequate thermal insulation. Design for containment. Monitor for liquid leakage. Monitor cabin atmosphere for toxic gases. Shroud and ventilate test unit.
6.4.4	Same as 6.4.1	Same as 6.4.1
6.4.5	High or low oxygen partial pressure. High or low total pressure.	Monitor partial and total pressures. Provide manual overrides on automatic controls. Provide pressure relief valves. Provide audio/visual warning devices.
6.4.6	Same as 6.4.5	Same as 6.4.5
6.4.7	Burns. Toxic and caustic liquids. Toxic gases. Flammable and explosive gases.	Design adequate thermal insulation. Design for containment. Monitor for liquid leakage. Provide means to neutralize acidic/alkaline contamination. Monitor cabin atmosphere for toxic gases. Shroud test unit and ventilate to contaminant removal apparatus.
6.4.8	Burns. Toxic and caustic liquids. High CO_2 partial pressure.	Design adequate thermal insulation. Design for containment. Monitor for liquid leakage. Provide means to neutralize alkaline contamination. Monitor CO_2 partial pressure.
6.4.9	Burns. Toxic and caustic powdery materials. Toxic atmosphere gases.	Design adequate thermal insulation. Design for containment. Monitor cabin atmosphere for toxic gases.
6.4.10	Suit pressurization failure. Suit O_2 supply failure. Suit CO_2 removal failure.	Continuous visual monitoring. Continuous biomedical monitoring. Continuous suit atmosphere monitoring by instruments. Provide means for rapid retrieval into airlock and rapid pressurization of airlock.
6.4.11	Same as 6.4.10	Same as 6.4.10
6.4.12	Same as 6.4.1	Same as 6.4.1

VOLUME VIII

SECTION 7

MAN-SYSTEM INTEGRATION

SECTION 7

MAN-SYSTEM INTEGRATION

7.1 GOALS AND OBJECTIVES

The goal of Man-System Integration (MSI) research is to achieve optimum utilization and support of man in advanced space systems. To attain this goal, five basic research objectives have been specified by NASA:

a. Determine man's individual behavior characteristics and group dynamics in space.

b. Quantify human capabilities for performing physical and mental work as an operator and maintainer of space systems and equipment, and as a scientific investigator, and to provide data for decisions on the appropriate man/machine mix.

c. Develop operator equipment and technology for crew and cargo transfer, assembly, and maintenance internal and external to the space vehicle.

d. Develop the technology for habitable living areas for space vehicles.

e. Develop methods for crew selection, proficiency assessment, maintenance of skills, and to identify training requirements.

A wide variety of experiments have been proposed toward achieving these objectives. To satisfy the format and objectives of this document, these experiments have been categorized into four classes:

a. Behavioral Effects - Those experiments designed to determine the effects of prolonged exposure to the spaceflight environment on man's individual and group behavior.

b. Performance Capability Assessment - Experiments designed to evaluate man-system performance capabilities in the spaceflight environment.

c. Habitability and Proficiency Maintenance - Experiments designed to evaluate man-system characteristics that maintain and/or prevent degradation of that performance.

d. Behavioral Effects and Performance in Rotogravitation - Experiments designed to evaluate man's behavior and performance capabilities in artificial gravity.

Typical experiments and/or representative groups of experiments have been selected from each class for inclusion in this document. Experiments concerned with developing and evaluating man-systems but whose primary objective places emphasis on the

engineering evaluation of hardware were not considered in this FPE. For example, an experiment to develop and evaluate an advanced astronaut maneuvering unit has been discussed under the Advanced Technology FPE rather than the Man-System Integration FPE.

7.2 PHYSICAL DESCRIPTION

The MSI facility includes equipment in three categroies, namely: 1) Units unique to the MSI FPE, consisting of the Human Research Centrifuge and the Mobility Unit; 2) Units which are part of the Life Sciences Common Operations Equipment (CORE); and 3) Units which are shared with another FPE. These equipment units are supplemented by experiment-peculiar equipment to form the apparatus required for each experiment. For several experiments, the MSI facility is the entire habitable volume of the spacecraft. The facility concept is illustrated in Figure 7-1.

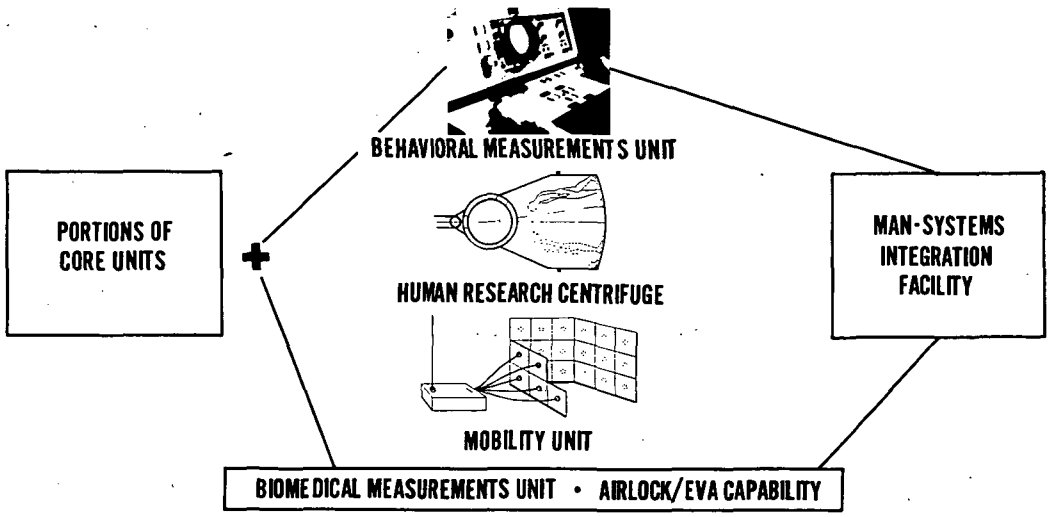


Figure 7-1. Life Sciences Man-System Integration

7.2.1 HUMAN RESEARCH CENTRIFUGE

7.2.1.1 Functional Capability. The Human Research Centrifuge, a typical installation of which is shown by Figure 7-2, has the capability of providing 6.5 g at a maximum angular velocity of 4.9 rad/sec. Maximum angular momentum is 1000 m-kg-sec (7225 ft-lb-sec) for this condition. A wide range of experiments can be supported by this device, including human physiological studies, performance assessment and habitability in a rotating environment, and studies of human physiological changes in

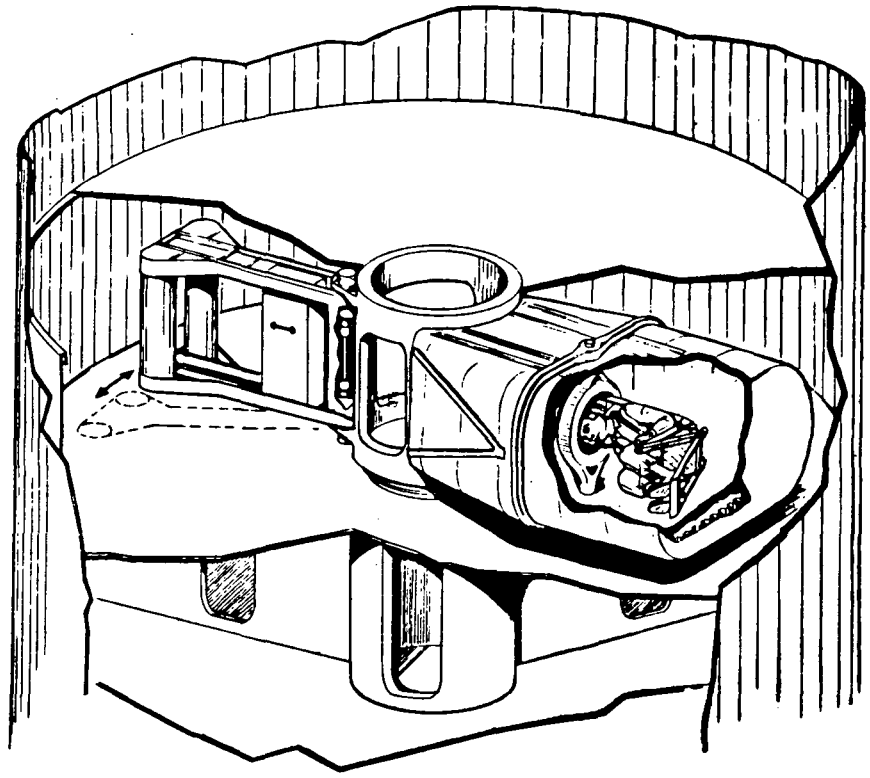


Figure 7-2. Human Research Centrifuge

zero g. The range of applicable experimental capability is listed in Table 7-1. Its experiment chamber provides 1.2 m (4 ft) by 2.3 m (7.5 ft) walking floor, 38 dm^3 (10 gallon) water supply and fluid handling system, and attachment fixtures for the orientation and support of experimental equipment. It features a television monitoring system and two-way voice communication with the subject. Individual experiments are supported by equipment kits which include a universal couch, hygiene package, habitability kit, bench task kit, etc.

7.2.1.2 Description. The principal features of the centrifuge are the experiment chamber, the hub, and the counterbalance assembly.

The experiment chamber is a room-like enclosure which houses all experiment activity. It is designed as a continuous shell and contains a walking floor and attachment fixtures for the orientation and support of experiment equipment.

The hub assembly serves as the interface connection between the experiment chamber, the counterbalance equipment and the spacecraft. The hub consists essentially of two ring structures connected by three equally spaced posts or columns, one of which

Table 7-1. Areas of Experimental Investigation Applicable to the Human Research Centrifuge

Human Tolerance to Angular Velocity
a. Vestibular and related phenomena b. Neurophysiological functions c. Motion sickness d. Cardiovascular functions
Tolerance to rapid changes of rotation
a. Active transition b. Passive transition
Effects of intermittent partial gravity on body functions
Human physiological and behavioral changes in zero-g
a. Vestibular and related phenomena b. Neurophysiological functions c. Relief of agravic syndrome d. Orthostatic tolerance to g e. Skill retention during inertial force re-application
Physiological Reconditioning after long term zero-g exposure
Self locomotion performance at partial-g
Performance after zero-g/artificial transition
Cargo handling at partial-g
Fine and gross motor performance at partial-g
Ataxia at partial-g
Man/Machine interaction in bio-centrifuge experiments
Eating and food preparation in partial-g
Physical Phenomena at partial-g
Personal hygiene at partial-g
Effects of partial-g on sleeping
Evaluation of waste management, stowage, equipment orientation, etc., in artificial-g
Evaluation of short radius, internal rotating device as operational support for zero-g station

is in line with the counterbalance assembly attachment and the other two aligned with the hub/chamber wall intersection. Openings between the posts provide access from within the hub into the experiment chamber and the centrifuge installation chamber. Interface with the spacecraft or experiment module is accomplished by providing a bearing (roller support system) and motor drive at one end of the hub. The center passageway may incorporate a stationary cylindrical sleeve, with appropriate access openings and doors, to permit traffic through the hub during centrifuge operation without exposure to rotating equipment. The hub also serves as a mounting structure for the main drive inverter, controls, and additional batteries.

7.2.1.2.1 Installation. The design illustrated by Figure 7-3 is applicable to a space vehicle having 6.1 m (240 in) cylindrical outer shell such as is provided by Skylab and allows a 1.17 m (42 in) clear passageway through the center of the vehicle. This basic design, however, is adaptable to Space Station internal installation, Space Station-attached module installation, and Shuttle-sortie concepts by the use of an expandable structural housing. Centrifuge chamber height should be approximately 1.65 m (65 in) to allow sufficient clearance for the rotating assembly. The bulkhead utilized for attachment of the roller support system must be sufficiently rigid to provide a high natural frequency for the total assembly. In addition, a control station for centrifuge operation must be provided in the near vicinity, with easy access between the control station and the experiment chamber, and connections for battery charging and water system servicing made available.

7.2.1.2.2 Centrifuge Characteristics. The maximum radial dimension of the centrifuge is 2.845 m (112.0 in) (to the bottom of the walking floor). The outside width of the experiment chamber is 1.372 m (54.0 in) which, with allowances for structure, provides a chamber floor width of 1.219 m (4.0 ft). Length of the walking floor is approximately 2.286 m (7.5 ft).

Maximum weight and moment of inertia of the rotating assembly during operation are 548 kg (1207 lb) and 204 m-kg-sec^2 (1475 ft-lb-sec^2) respectively, and the maximum momentum generated during experimentation (re-entry) is 1000 m-kg-sec (7225 ft-lb-sec). Maximum experimental capability required of the machine is 6.5 g, which corresponds to a maximum angular velocity of 4.9 rad/sec. Total facility equipment weight, including control station, counter momentum CMGs, and other stationary support systems is approximately 780 kg (1720 lb) at launch.

7.2.1.2.3 Major Subsystems. The major centrifuge subsystems characteristics are described briefly as follows:

a. Structure. Aluminum alloy sheet metal and machined fitting built-up assemblies make up the general centrifuge structure with the exception of the experiment chamber. The experiment chamber is designed as an integrally stiffened shell fabricated of graphite epoxy composite.

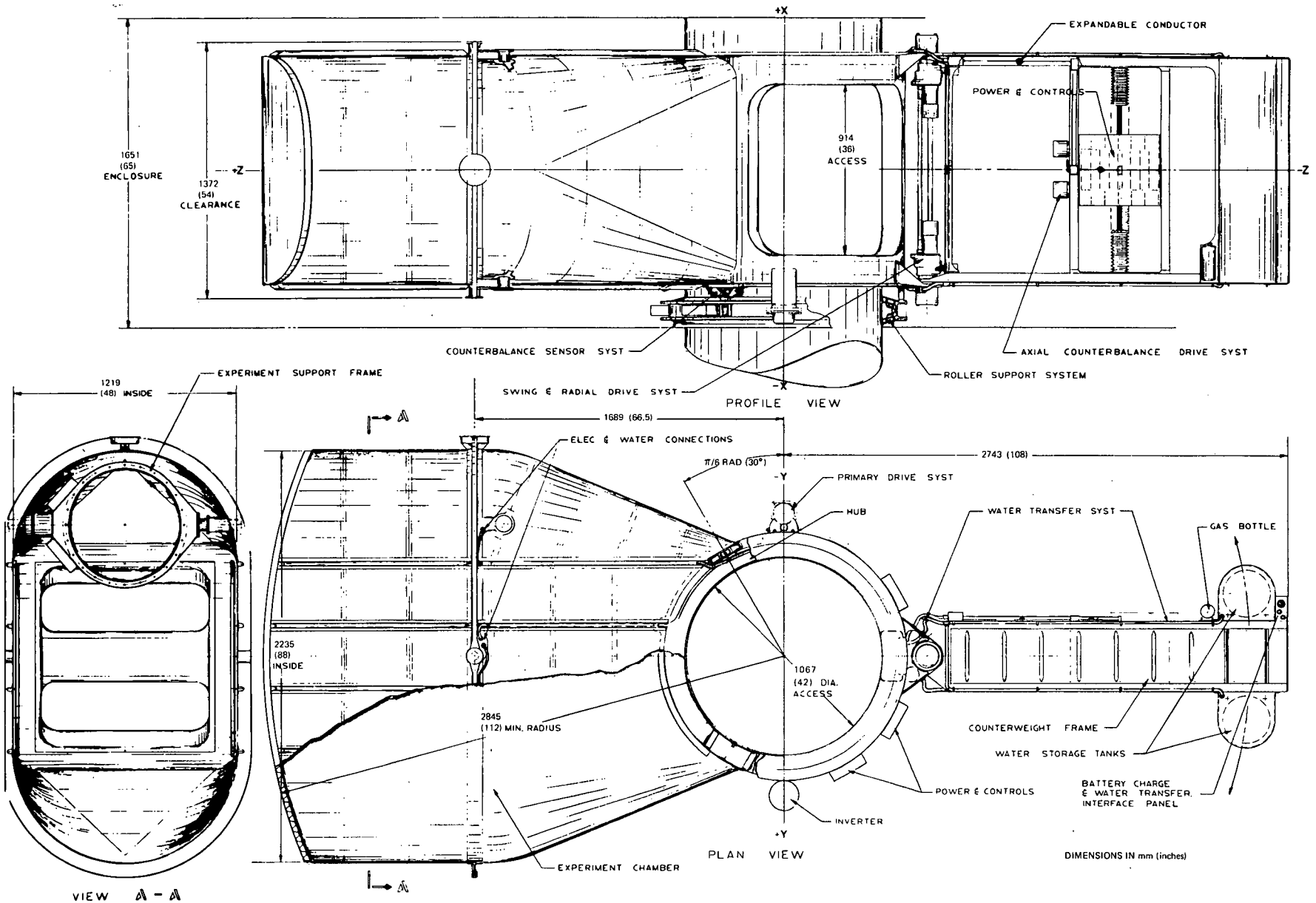


Figure 7-3. Human Research Centrifuge General Arrangement

b. Primary Drive. Primary rotation is provided by a voltage/frequency controlled 2.6 kW (3.5 HP) output AC motor mounted on the rotating assembly at the hub drive ring. It contains an integral gear reduction and is balanced against an inverter installed on the opposite side of the hub.

c. Power. Power for all equipment on the rotating section of the centrifuge is supplied by rechargeable batteries which are integrated with the counterweight. Power for the control console and countermomentum subsystem is supplied directly from the space station.

d. Communications. All communication with the centrifuge rotating assembly is accomplished by RF link. The communications system will probably include a TV link with a camera (2.9 MHz) and a low-power UHF transmitter on the centrifuge and a receiver at the control console; a low-power VHF link for PCM data (25 kbps science plus 0.5 kbps housekeeping) and voice communications, with the transmitter on the centrifuge and the receiver at the console; and a low-power VHF link for command control and voice communications, with the transmitter at the console and the receiver on the centrifuge.

e. Imbalance Sensing. Imbalance sensing is accomplished through a network of three force-sensor pairs, mounted between the drive ring and the centrifuge hub structure. The sensor pairs are spaced at intervals of $2\pi/3$ rad (120°) and are aligned with the hub structural posts.

f. Counterbalance. Counterbalance of the centrifuge is accomplished by automatic positioning of the 91 kg (200 lb) counterweight in response to imbalance forces and torques computed from the sensor network signals. The counterweight is positioned by rotation of the counterweight swing frame through a range of $\pm \pi/3$ rad ($\pm$ 30°) from center, linear translation of the counterweight carriage within the swing frame of 1.12 m (44 in), maximum, and axial translation of the counterweight within the carriage of $\pm$0.356 m (14 in) from center. This motion envelope allows full static and dynamic balancing of the machine. Dual motor/gear drive units for swing and radial counterweight motion are located at the top and bottom pivot collars on the swing frame. The axial drive unit is an integral part of the counterweight.

g. Water. A water system is integrated into the centrifuge. Water storage and collection tanks with a capacity of 38 dm^3 (10 gal.) are located at the outboard end of the counterweight swing frame. The system provides water on demand by pressure expulsion of fluid from the supply tanks.

h. Countermomentum. Dual single-degree-of-freedom control moment gyros (CMGs) are required on the module/space station to absorb the spin-up momentum of the centrifuge. Based on a maximum momentum requirement of 1000 m-kg-sec (7225 ft-lb-sec) and an initial momentum vector angle of $\pi/6$ rad (30°), each

gyro must be sized for 290 m-kg-sec (2100 ft-lb-sec). A weight estimate of 144 kg (250 lb) per unit is considered conservative at this time.

i. Control Console. The control console is also mounted on the module/Space Station. It provides two-way voice communications and a TV monitor, as well as equipment controls and monitors.

7.2.1.3 Equipment Unit Summary. The following is a summary of the equipment unit:

a. Weight: 1) Rotating assembly (not including subject) 419 kg (923 lb)
2) Total equipment unit (launch weight) 780 kg (1720 lb)

b. Moment of Inertia: Maximum of 204 m-kg-sec^2 (1475 ft-lb-sec^2)

c. Angular Velocity: Maximum of 4.9 rad/sec

d. Experimental "g" Capability: Maximum of 6.5 g

e. Power: 250 watts at 28 Vdc will be required during all operations for the control panel and countermomentum subsystem. Batteries will be recharged from the Space Station power system after each centrifuge operation. Battery charge efficiency will require the space station to supply 1.16 times the battery energy (W-hr) used during an operation. Battery characteristics are: Nominal charge capacity, 100 A-hr; full charge voltage, 36.5 Vdc; maximum charge current, 50 A. The recharge rate will be dependent upon time between operations and power availability from the Space Station.

f. Digital Data: Maximum rate is 25.5 kbps, including 0.5 kbps for centrifuge housekeeping data. Maximum science data output per operation is 15 x 10^6 bits.

g. Communications: Voice on space station intercom for operator. Approximately 300 m (1000 ft) of tape storage for voice communication. Approximately 750 m (2500 ft) of tape storage for TV link.

h. Resupply: 5 kg (11 lb) of cine film or video tape equivalent.

i. Life Support: Provide shirtsleeve environment.

j. Control: Space Station computer access and interface for command storage of 50 to 100 commands.

7.2.2 MOBILITY UNIT

7.2.2.1 Functional Description. Equipment in this unit has the capability of measuring pertinent parameters associated with man's mobility and stability abilities. As a result, it is the primary unit utilized in locomotion studies, as well as functioning as

a support unit to several other MSI research categories which require the crew's movement from one place to another, or a crewman's stabilization at a worksite. The equipment consists of a portable metabolic analyzer, an impact force detector, portable accelerometers, an event timer, and selected restraints and locomotion aids.

Specific functions of each of these pieces of equipment are:

a. Portable metabolic analyzer. A face mask picks up exhaled breath and transports a sample per breath to the analyzer. The analyzer takes a count of oxygen consumed and of CO_2 produced per breath. The transmitter produces a signal for each of the above; the signal is received and recorded by instrumentation outside the experiment task area. The recorder will read directly in metabolic rate on a breath-to-breath basis.

b. Impact force detector. The impact pickup(s) will determine the location and impact force that a crewman generates as he strikes or utilizes these instrumented areas for locomotion and/or restraint. Areas of the panels to be instrumented are proposed to be approximately 0.15 x 0.15 m (6 x 6 in) square. They will comprise the interior surfaces of the measuring device, will be integral parts of the panel, and may use an accelerometer or strain gage type of instrument. The important factor is the quality and accuracy of the readout for subjective analysis.

c. Portable accelerometers. The accelerometer detects acceleration and deceleration of the unit as placed upon the crewman's body. Detection and transmission will be constant from time of activation to time of deactivation.

d. Event timer. The event timer will be a 12-hour timer capable of an output to a recording monitor. Its purpose is to enable the analyzer to key and identify the time of occurrence of specific events. Readout will be valid to $\pm$ 1.0 sec.

e. Selected restraints and locomotion aids. These devices have a broad range of physical characteristics (e.g., handholds, handrails, Dutch shoes, variable flexibility tethers, cage restraints, STEM attachments), but share a commonality in that they all enhance astronaut locomotion, stabilization, or both.

7.2.2.2 Description. A physical description and brief outline of the operating characteristics of the Mobility Unit instrumentation is included below:

a. Portable metabolic analyzer. This unit is shown in Figure 7-4. The face mask provides for controlled inhalation/exhalation of breath. The analyzer/transmitter measures oxygen consumption and CO_2 production, on the subject's body. Results of the count or measurement are transmitted in the form of raw data or of actual metabolic count to a receiver/recorder. Purpose of the unit is to give the man

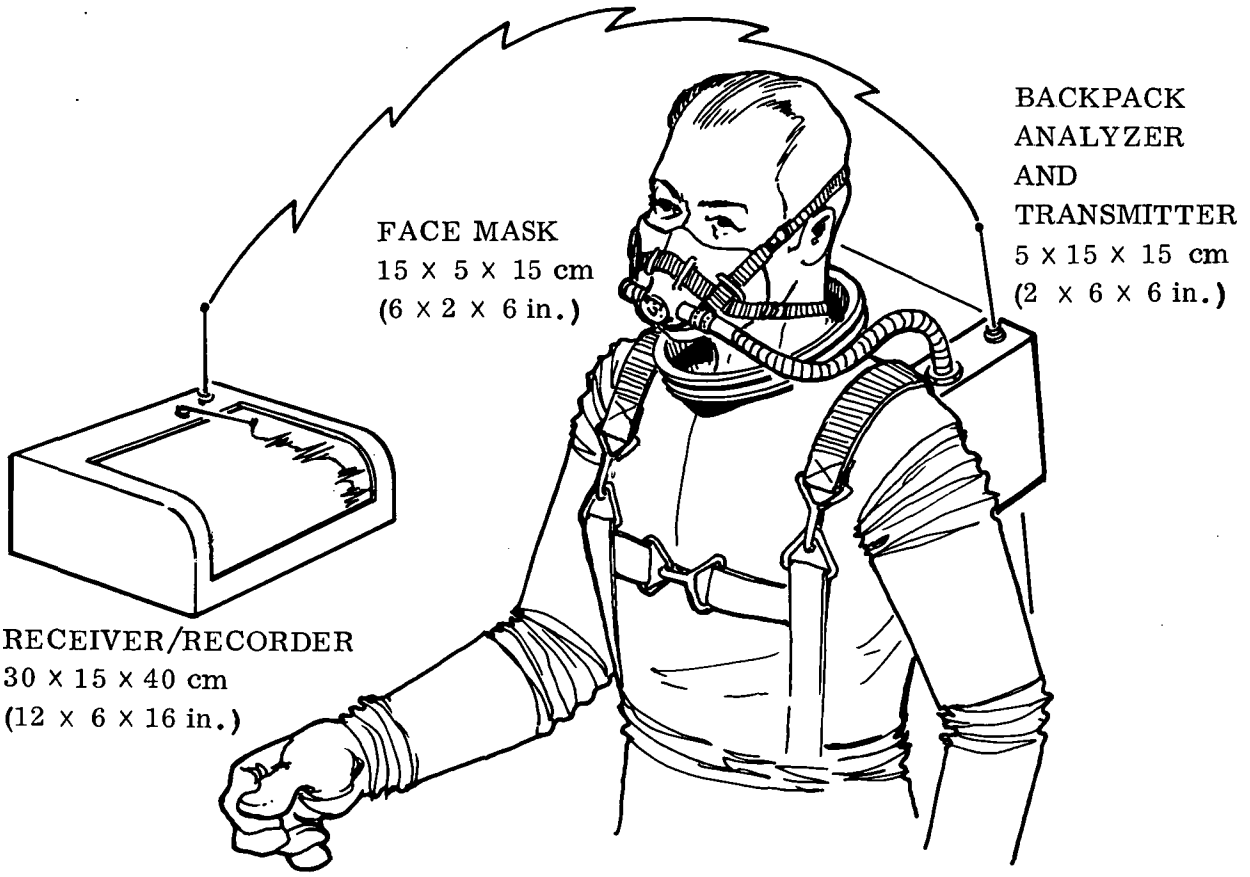


Figure 7-4. Portable Metabolic Analyzer

total mobility and still accomplish metabolic analysis. It requires one face mask, one analyzer back- or chest-pack, one transmitter, one receiver.

The man dons mask and back pack, and adjusts to comfortable and workable fit. Transmitter and analyzer power switch is activated and checkout procedure is followed. Transmitter and analyzer power is conserved until experiment task is to be performed. Upon start of experiment, unit is activated as is the receiver/recorder unit. Upon completion of experiment task, the analyzer/transmitter and receiver/recorder are deactivated.

b. Impact force detectors. An instrument to detect and transmit an impact upon a surface, it will be capable of identifying the force or pressure of the impact and the location of the impact. The output signal will be compatible with the recording equipment utilized in this experiment cluster (Figure 7-5).

The impact pickups are an integral part of the "building block" panel that is utilized to build the specific experiment task enclosure. Activation and checkout of the pickups is by the experiment monitor. The recording of the pickup signal

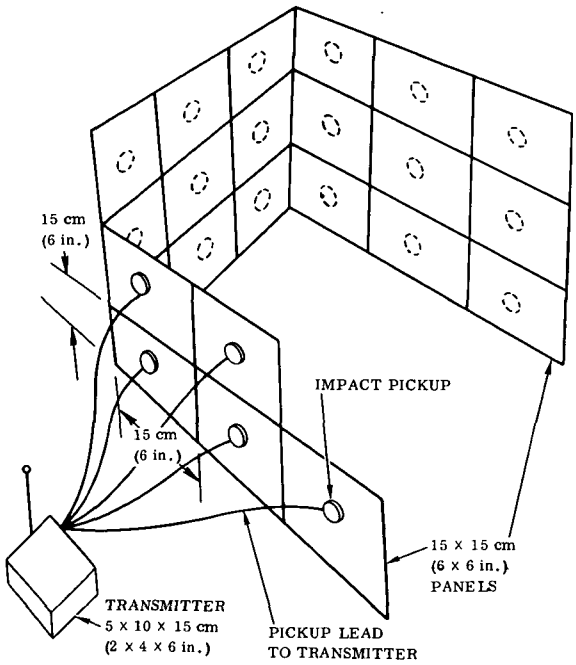
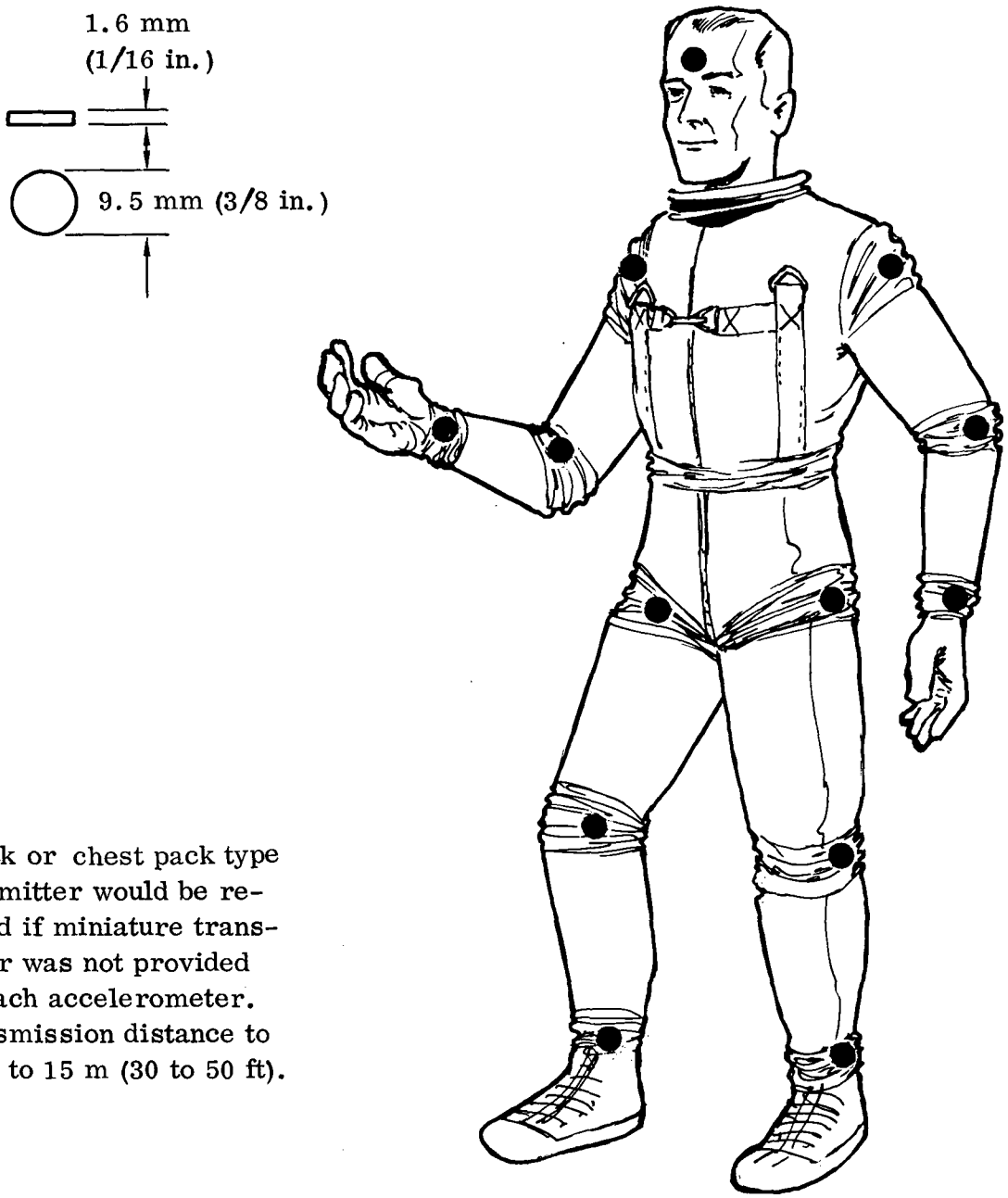


Figure 7-5. Impact Force Detector

is also monitored by the equipment monitor. The pickups as mounted on the panels must be capable of recording the impact of a man's mass of 55 kg (120 lb) to 100 kg (220 lb). In addition, the man may be required to locomote with a cargo mass. The impact at worst condition will be a point contact. Reliability and long life is an important factor in the development of the impact pickups.

c. Portable accelerometers. Each man-mounted accelerometer(s) (Figure 7-6) contains its own transmitter or is hard-wired to a man-mounted multichannel transmitter. Individual accelerometers must be of minimum size possible for mounting on body points such as ankle(s), knee(s), hip(s), shoulder(s), elbow(s), wrist(s) and head. The accelerometers will describe the acceleration or dynamic motion profile of the man during a specific locomotion-experiment task(s). The means of defining or deriving the data is not of importance as long as the crewman is not interfered with during the task performance, and the results are consistent, repeatable and measurable. The system will be activated, checked out, monitored, and deactivated by the experiment monitor. Units will be reusable and adaptable from man to man for repeating of the experiment.

d. Event timers. The recording event timer starts recording at the beginning of an experiment and stops at the end of the experiment. Event timer is activated, checked out, and deactivated by the experiment monitor. Recorder will read out the time in concurrence with the event of the specific experiment.



A back or chest pack type transmitter would be required if miniature transmitter was not provided for each accelerometer. Transmission distance to be 10 to 15 m (30 to 50 ft).

Figure 7-6. Portable Accelerometers

Table 7-2 is an equipment list for the Mobility Unit. The equipment unit is summarized as follows:

a. Weight: 68 kg (150 lb)

b. Volume: 2.48 m^3 (84 ft^3)

c. Power: Average, 40 watts; maximum, 50 watts; minimum, 30 watts; % Time at Max. Power, 50; % Time at Min. Power, 50; portable transmitters battery-powered.

Table 7-2. Equipment List

Name	Features	Weight Kg(lb)	Volume $m^3(ft^3)$	Power (W)	Envelope Operational
Portable Metabolic Analyzer	Transmission range 10 to 15 m (30 to 50 ft)	18(40)	1(35)	*	15 x 5 x 15 cm (6 x 2 x 6 in.) face mask 5 x 15 x 15 cm (2 x 6 x 6 in.) transmitter 30 x 40 x 15 cm (12 x 6 x 6 in.) receiver/recorder
Impact Force Detectors	15 x 15 cm (6 x 6 in.) base panel locations are function of exp. setup	16(35)	0.8(28)	35	15 x 15 cm (6 x 6 in.) panel plus 5 x 10 x 15 cm (2 x 4 x 6 in.) transmitter
Portable Accelerometers	Transmission range 10 to 15 m (30 to 50 ft)	11(25)	0.6(20)	*	1.6 mm x 9.5 mm (1/16 x 3/8 in.) dia (each sensor) + backpack transmitter 5 x 10 x 15 cm (2 x 4 x 6 in.)
Event Timer	12-hour timer		0.03(1)	5	5 x 10 x 10 cm (2 x 4 x 4 in.)
Selected Restraints and Locomotion Aids	Varied handholds, handrails, Dutch shoes, STEM booms, etc.	23(50)	0.6(20)	0	

* Battery powered.

7.2.3 BEHAVIORAL MEASUREMENTS UNIT

7.2.3.1 Functional Capability. Behavioral measurement of the sensory, psychomotor, and complex processes is provided by this unit. Specific measurements are:

FUNCTIONAL AREA	MEASUREMENTS
Sensory Processes	Visual - Depth Perception
	Brightness Threshold
	Visual Field
	Flicker Fusion Frequency
	Phorias
	Acuity
	Glare Recovery
	Color Perception
	Auditory - Absolute Threshold
	Pitch Discrimination
	Temporal Acuity
	Speech Intelligibility
	Cutaneous - Pressure Threshold

Psychomotor Processes	Fine Motor Abilities - Steadiness Complex Motor Abilities Gross Body Coordination Continuous Control - Tracking Reaction Time - Simple and Complex
Complex Processes	Time and Motion Concentration (Problem Solving) Complex Perceptual Processes Mediational Processes Memory Processes

7.2.3.2 Description. Three major equipment elements will accommodate the range of selected behavioral measurements. These are the vision tester, audiometer, and performance panel. Each device is designed to permit self-administration of the tests, computer control of the stimulus sequence, automatic scoring and data processing, and the capability for repeated measures on the same subjects without contamination of data by practice effects.

The vision tester utilizes the computer system to set up and present stimuli and to record and score responses. Major elements under computer control are the film transport mechanism, shutter, and optical wedge to permit control over the spatial, temporal, and luminance characteristics of the test stimuli. Simple, discrete, or multiple-choice responses can be made without viewing the response panel. A lens turret provides optics for near and far viewing.

The audiometric test utilizes a Rudmose ARJ-4A Bekesy-type audiometer, which automatically presents sequential pure-tone stimuli in the range of 500 to 6000 Hz to each ear. In addition to the normal audiogram plot, the instrument presents the amplitude excursions at each frequency to the computer for averaging and subsequent printout of these values.

The performance panel accommodates the display and response hardware for the majority of measures of psychomotor and complex behavior.

Stimulus control is provided by the data management system, whereas the stimuli themselves are generated by relatively simple lights, meters, numerical indicators, and a CRT. Program control and test status are presented by "test in progress", "ready", and "trial" signal lights.

The response keys serve a multiple purpose, acting as the response input devices for simple psychomotor tests, reaction time responses, and choice responses required in the measurement of complex behavior.

The critical tracking task equipment, which consists of three units -- a display, a single-axis hand controller, and a solid state special purpose analog computer -- provides considerable flexibility. It may be used in a tracking task whose difficulty increases in a preprogrammed manner, or as an adaptive device. In the latter mode, tracking task difficulty is continually adjusted, based on inputs from a source such as a secondary task or a physiological parameter.

A potential capability for additions or modifications of the behavioral element is provided by the TV display and associated tape recorder. This device would permit the presentation of many types of visual, symbolic, or alphanumeric information from a prerecorded tape, which can also include timing and command signals for the data management system.

7.2.3.3 Equipment Unit Summary. The following is a summary of the equipment unit:

a. Weight: 90 kg (200 lb)

b. Volume: 1 m^3 (35 ft^3)

c. Power: Average, 150 watts; maximum sustained, 300 watts

d. Envelope: 150 × 107 × 61 cm (60 × 42 × 24 in)

e. Data Acquisition Rate: 0.2 kbps.

7.2.4 OTHER EQUIPMENT. This FPE includes other equipment which is shared with other Life Sciences FPEs as follows:

Equipment Unit	Location	Reference Section
Visual Records & Microscopy Unit	CORE	B.1.1
Data Management Unit	CORE	B.1.2
Life Science Experiment Support Unit	CORE	B.1.3
Maintenance, Repair, & Fabrication Unit	CORE	B.1.6
Ancillary Storage	CORE	B.1.7
Airlock/EVA Capability Unit (also *shared with FPE 6, LSPS)	*	B.4
Biomedical Measurements Unit	FPE 1	1.2

7.3 EXPERIMENT REQUIREMENTS SUMMARY

Table 7-3 summarizes experiment requirements.

Table 7-3. Experiment Requirements Summary

EXPERIMENT	MASS (WEIGHT) kg	(lb)	VOLUME* m^3	(ft^3)	ENVELOPE m	(ft)	POWER REQUIREMENTS* watts	CREW SKILLS	ENVIRONMENT REQUIREMENTS	EXPERIMENT TIME LIMITS	DATA REQUIREMENTS	PREFLIGHT SUPPORT	POSTFLIGHT SUPPORT
7.4.1.1 Effects of Space Flight Environment on Sensory Processes	210	(465)	2.1	(73)			Cont. 0 Peak 400 Peak Dur.(hr) 1.85	Any (Subject) 12,21	Nominal Spacecraft. Controlled Illumination and Noise Levels	A 3.5-hr Test Every 20 Days for Each Subject	TV, Hr/Day Data Rate, bps Coll. Time, hrs/day 3.5	Measurement Baselines	Measurement Baselines
7.4.1.2 Effects of Space Flight Environment on Cognitive Processes	90	(200)	1.0	(35)			C - 0 P - 100 PD - 3.25	Any (Subject) 12, 21	Nominal Spacecraft. Free From Visual & Auditory Distractions	A 2.0-hr Test Every 20 Days for Each Subject	TV - 0 DR - 100 CT - 2.0	Measurement Baselines	Measurement Baselines
7.4.1.3 Effects of Space Flight Environment on Psychomotor Functions	95	(210)	1.0	(37)			C - 0 P - 150 PD - 3.25	Any (Subject) 12, 21	Nominal Spacecraft	A 2.0-hr Test Every 10 Days for Each Subject	TV - 1.75 DR - 100 CT - 2.0	Measurement Baselines	Measurement Baselines
7.4.1.4 Effects of Space Flight Environment on Individual and Group Dynamics	8	(17)	0.14	(5)			C - 0 P - 400 PD - 12.0	Any (Subject) 21	Nominal Spacecraft	Maximum of 12 hr Every 30 Days	TV - 12.0 DR - 100 CT - 12.0	Measurement Baselines	
7.4.2.1 Cargo-Handling Capabilities†	360	(800)	0.35	(12.5)			C - 0 P - 220 PD - 1.5	Any (Subject) 21	Nominal Spacecraft & EVA	A 1.5-hr Test Ten Times a Month	TV - 1.5 DR - 100 CT - 1.5		
7.4.2.2 Assembly, Deployment, Maintenance, and Repair Capabilities†	30	(65)	0.08	(3)			C - 0 P - 400 PD - (2.0)	Any (Subject) 12 21	Nominal Spacecraft & EVA	A 2.0-hr Test Every 30 Days for Each Subject	TV - 2.0 DR - 100 CT - 2.0		
7.4.2.3 Locomotion and Restraint Capabilities†	70	(150)	2.4	(84)			C - 0 P - 50 PD - 2.0	Any (Subject) 21	Nominal Spacecraft & EVA	A 2.0-hr Test Every 30 Days for Each Subject	TV - 2.0 DR - 100 CT - 2.0		
7.4.2.4 System Controller Capabilities†	43	(95)	0.20	(7)			C - 0 P - 225 PD - 0.25	Any (Subject) 21	Nominal Spacecraft	15-min Tests Per Subject at 21-Day Intervals	TV - 0.25 DR - 100 CT - 0.25	Measurement Baselines	
7.4.3.1 Interior Configurations, Environment, and Decor	10	(22)	0.14	(5)			C - - P - 165 PD - TBD	Any (Subject) 21	Nominal Spacecraft	Continuous Observation of Habitable Areas Over Mission Duration	TV - 24.0 DR - 100 CT - 24.0		
7.4.3.2 Off-Duty Activities and Facilities	5	(11)	0.06	(2)			C - 50 P - 155 PD - 0.16	Any (Subject) 21	Nominal Spacecraft	10-min Per Subject at 30 Day Intervals	TV - 8.0 DR - 100 CT - 8.0		
7.4.3.3 Skill Retention and Assessment	820 (Max)	(1800)	10 (Max)	(360)			C - 0 P - 250** PD - 1.0	Any (Subject) 11, 12, 13, 21	Nominal Spacecraft	A 1.5-hr Test Weekly Per Skill	TV - 1.5 DR - 100 CT - 1.5	Measurement Baselines	

*Includes common FPE Equipment.

**Does not include battery recharging requirements.

† Add 217 kg (479 lb), 2.5 m^3 (88 ft^3), and 700 watts additional power when Airlock/EVA Capability Unit is req'd.

Table 7-3. Equipment Requirements Summary, Contd

EXPERIMENT	MASS (WEIGHT) kg (lb)	VOLUME* m^3 (ft^3)	ENVELOPE m (ft)	POWER REQUIREMENTS* watts	CREW SKILLS	ENVIRONMENT REQUIREMENTS	EXPERIMENT TIME LIMITS hours	DATA REQUIREMENTS	PREFLIGHT SUPPORT	POSTFLIGHT SUPPORT
7.4.4.1 Locomotion and Balancing Capabilities in Rotogravitation	780 (1720)	10 (360)		C - 0 P - 250** D - 1.0	Any (Subject) 11, 12, 13, 21	Nominal Spacecraft	A 1.0-hr Test Every 6 Days for Each Subject	TV - 1.0 DR - 2550 CT - 1.0		
7.4.4.2 Fine Psychomotor Capabilities in Rotogravitation	780 (1720)	10 (360)		C - 0 P - 250** D - 2.5	Any (Subject) 11, 12, 13, 21	Nominal Spacecraft	A 3.0-hr Test Every 12 Days for Each Subject	TV - 3.0 DR - 2550 CT - 3.0	Measurement Baselines	
7.4.4.3 Cargo-Handling and Gross Psychomotor Capabilities in Rotogravitation	780 (1720)	10 (360)		C - 0 P - 250** D - 1	Any (Subject) 11, 12, 13, 21	Nominal Spacecraft	A 1.0-hr Test Every 20 Days for Each Subject	TV - 1.0 DR - 2550 CT - 1.0		

*Includes common FPE Equipment.

**Does not include battery recharging requirements.

†Add 217 kg (479 lb), 2.5 m^3 (88 ft^3), and 700 watts additional power when Airlock/EVA Capability Unit is req'd.

7.4 EXPERIMENT PROGRAM

The Man-System Integration Research program is comprised of a group of representative experiment classes, each supported by a group of representative experiments. These selected representative experiments provide experiment support requirements and other spacecraft and mission impacts to a level ample to characterize the requisite Man-Systems Integration Research Facility. Table 7-4 enumerates the representative experiment classes and representative experiments that scope the experiment program.

Table 7-4. Man-System Integration Research Program

Section	Title
7.4.1	Experiment Class: Behavioral Effects
7.4.1.1	Experiment: Effects of the space flight environment on the sensory processes
7.4.1.2	Experiment: Effects of the space flight environment on the cognitive processes
7.4.1.3	Experiment: Effects of the space flight environment on psychomotor functions
7.4.1.4	Experiment: Effects of space flight environment on individual and group dynamics
7.4.2	Experiment Class: Performance Capability Assessment
7.4.2.1	Experiment: Cargo handling capabilities
7.4.2.2	Experiment: Assembly, deployment, maintenance and repair capabilities
7.4.2.3	Experiment: Locomotion and restraint capabilities
7.4.2.4	Experiment: System controller capabilities
7.4.3	Experiment Class: Habitability and Proficiency Maintenance
7.4.3.1	Experiment: Interior configurations, environments and decor
7.4.3.2	Experiment: Off-duty activity and facilities
7.4.3.3	Experiment: Skill retention and assessment in long-duration space flight
7.4.4	Experiment Class: Behavioral Effects and Performance in Rotogravitation
7.4.4.1	Experiment: Locomotion and balancing capabilities in rotogravitation
7.4.4.2	Experiment: Fine psychomotor capabilities in rotogravitation
7.4.4.3	Experiment: Cargo handling and gross psychomotor capabilities in rotogravitation

7.4.1 BEHAVIORAL EFFECTS

7.4.1.1 Effects of the Spaceflight Environment on the Sensory Processes

7.4.1.1.1 Scientific or Technical Objectives. These experiments, a portion of the Behavioral Effects class of experiments, will determine the effects of exposure to the spaceflight environment on man's sensory processes.

7.4.1.1.2 Description. These experiments require the measurement of visual, auditory, cutaneous, orientation, and motion sensing parameters for each crewman approximately every 20 days during the initial crew cycle. The basic equipment of the Behavioral Measurements Unit, discussed in Section 7.2.3, will allow self-administration of most of the tests, computer control of the stimulus sequence, automatic scoring and data processing, and repeated measures on the same subjects without contamination of data by practice effects. As an example, the vision tester will use the computer system to set up and present stimuli and to record and score responses. Major elements under computer control will be the film transport mechanism, shutter, and optical wedge to permit control over the spatial, temporal, and luminance characteristics of the test stimuli. Simple, discrete, or multiple-choice responses will be made without viewing the response panel. A lens turret will provide optics for near and far viewing.

Periodic measurements and potentially related physiological and environmental parameters needed for the study of cause-and-effect relationships for any observed changes will be recorded for a number of crewmen over several missions. Each visual measurement session is estimated to require 40 minutes per crewman, with no more than five responses expected on each of ten visual parameters. Each auditory measurement session is estimated to require 75 minutes per crewman with no more than seven responses expected on each of six auditory parameters. Each motion/orientation measurement session will require 75 minutes per crewman with no more than five trials expected on each of five parameters.

Experiment-peculiar equipment may be required as additional sensory process evaluations are added to the basic capability.

7.4.1.1.3 Observation/Measurement Program. Visual, auditory, cutaneous, and motion sensing/orientation measurements will be recorded as indicated by Tables 7-5, 7-6, and 7-7. Baseline measurements of the crew population will be required before and after each flight to establish normative values and deviations. Each subject will be tested on approximately 20-day intervals throughout the mission. Any measurement may be interrupted for emergency requirements, but that measurement must be reported later. All measurements will be taken with the subject seated at the Behavioral Measurements Unit consoles or in the litter chair, aided by the test administrator when necessary.

Table 7-5. Visual Measurements

Vision Parameter	Description	Units in Which Measured	Range (Signif. Digits)
Acuity	The smallest space the eye can see between parts of a target; target at various distances and levels of illumination. Low levels of background illumination increase test sensitivity for detecting subject's changes in acuity.	Millimeters to better than one decimal point	3
Field	Size of arc through which moving objects can be detected.	$\pi/2$ radians (90°) peripherally in all 12 principal meridians	2
Phorias	Horizontal and vertical deviations from center of fixation for both far and near vision.	Radians from center of fixation	
Critical Flicker Fusion Frequency	Frequency at which pulsed light appears to be of constant intensity.	Neighborhood of 40 Hz	2
Depth Perception	Discrete identification of objects judged to be equidistant at various distances and levels of illumination.	Percent distance traveled	3
Color Perception	Perception of each of full range of colors, red through yellow.	Hues	2
Dark Adaptation	Time to adapt to darkened conditions and level of brightness required to detect a light.	Candela/meter^2, seconds of time	4

Table 7-5. Visual Measurements, Contd

Vision Parameter	Description	Units in Which Measured	Range (Signif. Digits)
Brightness Threshold	Smallest unit of light of given frequency that can be seen under darkened conditions.	cd/m^2	3
Glare Recovery	Time to recover from exposure to glare and see a light of given brightness.	Seconds of time and cd/m^2	4
Accommodation	Visual acuity for distance after fixating near object.	Dioptens	2

Visual accommodation has been suggested as an additional visual parameter that should be measurable by the Behavioral Measurements apparatus. Sound localization and auditory detection/discrimination of motion also have been added as having possible application to applied requirements.

As physiological and environmental parameter data must be related to sensory experiment data to evaluate observed parametric changes, an assumption is made that these data will be recorded and made available on a mission time line.

7.4.1.1.4 Interface, Support, and Performance Requirements. The sensory experiments will be conducted in the normal pressure, temperature, and zero-g environment of the space vehicle. Visual experiments will require a viewing hood or a room where the experimenter can extinguish background illumination on demand. Auditory experiments will require a reasonably quiet room with the test subject shielded from extraneous noise and distracting visual stimuli. The experiments will not be affected by orbit altitude, inclination, magnetic field, pointing requirements, etc.

Power requirements are estimated to be 200 watts maximum for the visual experiments with a 100 watt average, 10 watt maximum for the auditory experiments with a 10 watt average, a minimal requirement for the cutaneous experiments, and a 400 watt maximum for the litter chair with a 180 watt average.

Discrete bits of data will be obtained with each observation by each subject. Generally, the subject will use a keyboard for entering identity, test, date, and time information and his observations during test administration. Speech-intelligibility data may be repeated onto a separate tape which will be stored for post-mission analysis. The sensory data need not be evaluated in real time during the mission (with the

Table 7-6. Auditory and Cutaneous Measurements

Auditory Parameter	Description	Units in Which Measured	Range (Signif. Digits)
Pitch Discrimination	Ability to discriminate sounds primarily by frequency; to be measured by matching variable test signals with selected fixed or standard signals (paired comparisons).	Frequency range 100 Hz to 10,000 Hz. Intensity limited to 70 db re 0.0002 dyne/cm^2.	2
Temporal Acuity	Accuracy in measuring the length of the quiet interval between pulses of noise in very brief (5 second) trains of noise.	Noise pulse duration range. Interpulse interval range. Noise pulse level range	50 - 1000 msec 0 - 250 msec 0 - 50 db
Absolute Threshold	Intensity level below which sound cannot be heard; measured for eight different frequency levels, 100, 250, 500, 1k, 2k, 4k, 6k and 10k Hz.	Signals below 2000 Hz should vary no more than ± 10 Hz; signals above 2000 Hz should vary no more than ± 20 Hz.	3
Speech Intelligibility	Efficiency of voice communications, measured as length of time required to hear a list of words and the number of items heard correctly.	Time in seconds and number of words repeated correctly on tape.	6
Sound Localization	Amount of error in degrees for blindfolded subject to localize the source of sound. This will relate to such maintenance activities as detection of pressure-seal leaks.	Accuracy (degrees) and Time (records)	6

Table 7-6. Auditory and Cutaneous Measurements, Contd

Auditory Parameter	Description	Units in Which Measured	Range (Signif. Digits)
Auditory Detection/Discrimination of Motion	Degrees of error in describing direction of sound movement manually on a prepared score sheet.	Degrees and Time	6
Cutaneous Parameter	**Description**	**Units**	**Range**
Pressure Threshold	Detect any degradation of cutaneous sensitivity which could affect performance of delicate tasks.	Grams/mm^2; measurement technique could utilize Von Frey hairs or electromechanical stimulation device.	At finger tip: Min. 3 g/mm^2 Max. 300 g/mm^2 (pain threshold)

exception of cardiovascular data during accelerations or traumatic illusionary data), but must be provided to the experiment investigator expeditiously following the mission. His evaluation can impact future missions, with a minimum impact being the reduction of parameters included for future testing.

7.4.1.1.5 Potential Role of Man. The spacecraft crew will be essential participants in the experiment, both as test subjects and as experimenters. As subjects, they will individually be required to spend approximately 3.5 hours taking the sensory test battery every 20 days for the duration of the mission. No special skills will be required of the subjects except for the normal preflight training on all experiment tasks. In addition, a preflight and postflight measurement program will be necessary to provide baseline data. All the measurements will be performed by each subject to determine normal values of the parameter and normal variations in the values.

As experimenters, the crew will be required to set up the experimental hardware, brief and debrief the test subjects, and observe and record the test data, either by operation of automatic data processing equipment or by manual or voice recording. One experimenter, an electromechanical technician thoroughly trained in use of the Behavioral Measurements Unit, will be required to conduct the experiments under the supervision of a behavioral scientist. At least two members of the crew should be qualified with the equipment.

Table 7-7. Orientation and Motion-Sensing Measurements

	Description	Measurement	Range in Signif. Digits
Angular Acceleration	Detection of rotation of whole body in litter-chair.	Time from onset of rotation to detection of motion. Radians of rotation and seconds of time.	Time - 2 Radians - 4
Linear Acceleration	Detection of motion, linear acceleration, in an acceleration chair.	Time from onset of motion to its detection. Cm of movement and seconds of time.	Time - 2 Distance - 2
Sensing Limb Position	Observer places subject's arm or leg and asks for a report of its position.	Error in radians from actual position and magnitude of distance.	Radians - 4 Distance - 2
Sensing Limb Movement	Detection of movement of limb; forearm lightly strapped on a support movable about a ball joint under the elbow.	Time from onset of motion to its detection, and the direction of change.	Time - 2 Radians - 4
Illusions - Visual Auditory Somesthetic	Discrepancies between subject's reports and observer reports of body and target position and movement and auditory stimuli.	Frequency of occurrence, amount of discrepancy between subject and observer reports.	Frequency - 1 Amount - 2
	Traumatic illusory observations.	Informal and opportunistically	Raw data

7.4.1.1.6 Available Background Data.

a. The "Visual, Auditory, and Orientation" experiments in Manned Space Flight Capability, Part 1 of 2 (Biomedicine, Behavioral, Man-Machine Integration), Earth Orbital Experiment Program and Requirements Study, McDonnell-Douglas Astronautics Co.

b. The "Visual Capabilities in Zero g and Partial g", the "Orientation Capabilities in Zero g and Partial g" and the "Behavioral Effects of Acoustic Environment" experiments in Requirements Study for a Biotechnology Laboratory for Manned Earth-Orbiting Missions - Phase II, McDonnell-Douglas Astronautics Co., MDC G0620, July 1970.

c. The "Visual Function," the "Auditory Function," the "Orientation Senses" and the "Somesthetic Function" experiments in Requirements Study for a Biotechnology Laboratory for Manned Earth-Orbiting Missions, NASA CR-1408, Volume I, August 1969.

d. The "Visual Function," the "Auditory Function," the "Orientation Senses," and the "Somesthetic Function" experiments in Requirements Study for a Biotechnology Laboratory for Manned Earth-Orbiting Missions, NASA CR-1409, Volume II, August 1969.

e. The "Behavioral Effects" experiment in Experiment Data Book - Space Station Program, General Electric Company - EL-103, Revision C, 12 June 1970.

f. The "Vision in Orbit" and the "Body Attitude Control and Stabilization in Zero-g" experiments in NASA Long Range Plan for Aerospace Medicine, 15 June 1969.

g. IMBLMS Functional Breadboard Performance Review, Phase B-3, General Electric Company, December 1969.

h. IMBLMS FBB - Phase B-3 - Final Summary Report, General Electric Company, February 1970.

i. IMBLMS Phase B3 - Functional Breadboard, Final Summary Report, LMSC-A963878, Lockheed Missiles and Space Company, February 1970.

j. Statement of Work, IMBLMS, Phase B4.

k. Proceedings on the Winter Study on Uses of Manned Space Flight, 1975 - 1985, NASA Science and Technology Advisory Committee for Manned Space Flight, NASA SP-196, December 1968.

7.4.1.2 Effects of the Spaceflight Environment on the Cognitive Processes

7.4.1.2.1 Scientific or Technical Objectives. The behavioral effects class of experiments contains a group of experiments whose objective is to determine the effects of long-duration space flight on man's cognitive processes, e.g.,

a. The collection and recall of information.

b. The mediational processes of learning, reasoning, and decision making, and communication of information to others.

7.4.1.2.2 Description. The experiments consist of periodic measurement of man's cognitive capabilities and potentially related physiological and operational parameters for a number of crewmen over an extended period of spaceflight. Methods for measuring parameters will include monitoring of proficiency in accomplishing day-to-day spacecraft/mission activities by ground controllers, and specific cognitive capability measurement tests utilizing the Behavioral Measurements Unit. These latter tests generally will be automated for self-administration. The computer-stored test items will be presented to each subject via the CRT on the console. The subject will use the keyboard to input his responses to the computer. A feature of the Behavioral Measurement Unit will enable precisely controlled, rapid sequential presentation of stimuli for short-term memory tests. Trial-by-trial knowledge of results will be provided the subject/operator automatically for all but the memory process tasks.

Potentially related information on physiological and operational parameters (sleep, drug intake, etc.) needs to be provided on a mission time-line to aid in identifying possible cause-effect relationships.

7.4.1.2.3 Observation/Measurement Program. Descriptions of the primary measurements are listed in Table 7-8 under the three subcategories of ability to perceive selected inputs, ability to process inputs, and ability to deliver selected outputs. Time is measured in seconds and tenths; accuracy is measured in formula score using items correct and errors. The 13 parameters presented in the table may each have a time score using four significant digits plus an accuracy score involving two significant digits. Thus, the 13 scores could each require 6 significant digits per score, or a maximum of 78 significant digits per subject per administration. The measurement program is estimated to require two hours per crewman at approximately 20-day intervals throughout the mission. Analytic study of crew-to-ground-control communications will be accomplished to derive speech perception and oral output communication measurements.

7.4.1.2.4 Interface, Support, and Performance Requirements. The cognitive experiments will be conducted in the operational environment and in the normal pressure, temperature, and zero-g environment of the spacecraft. Unrelated disturbances, such as visual or auditory distractions, should not be allowed to affect the experiment operation. Each subject needs an area where concentration is possible for accomplishing the test. The experiments will not be affected by orbit altitude, inclination, magnetic field, or pointing requirements. Power requirements are estimated to range up to 100 watts maximum with a 50 watt average. Data output will consist of recorded space/ground communications and keyboard responses stored until transmitted to ground or returned to Earth via Shuttle.

7.4.1.2.5 Potential Role of Man. The crew will be essential participants in the experiment as test subjects conducting self-administered tests. No specific crew skills will be required of the subjects other than complete familiarization with all experimental equipment and procedures.

Table 7-8. Primary Measurements

Parameters	Description
Complex Perceptual Inputs 1. Reading 2. Speech Perception 3. Pattern Discrimination 4. Numerical Relations 5. Identification of Signal in Noise	Time and accuracy in recognizing, comprehending, discriminating among objects presented as spoken and printed pictures, words, geometric patterns.
Mediational Processes 6. Learning 7. Recall 8. Reasoning 9. Problem Solving 10. Vigilance 11. Decision-Making	Time and accuracy in recalling and associating inputs, manipulating them and accomplishing computations to induce or deduce problem solutions.
Output or Complex Responses 12. Speaking 13. Writing	Time and accuracy in communicating, recording, delivering responses of a complex nature.

7.4.1.2.6 Available Background Data.

a. The "Cognitive Capability" experiment in Manned Space Flight Capability, Part 1 of 2 (Biomedicine, Behavioral, Man-Machine Integration), Earth Orbital Experiment Program and Requirements Study, McDonnell-Douglas Astronautics Co.

b. The "Cognitive Capabilities in Extended Spaceflight" experiment in Requirements Study for a Biotechnology Laboratory for Manned Earth-Orbiting Missions - Phase II, McDonnell Douglas Astronautics Company, MDC G0620, July 1970.

c. The "Higher Mental Functions" experiment in Requirements Study for a Biotechnology Laboratory for Manned Earth-Orbiting Missions, NASA CR-1408, Volume I, August 1969.

d. The "Higher Mental Functions" experiment in Requirements Study for a Biotechnology Laboratory for Manned Earth-Orbiting Missions, NASA CR-1409, Volume II, August 1969.

e. The "Behavioral Effects" experiment in Experiment Data Book - Space Station Program, General Electric Company, EL-103, Revision C, 12 June 1970.

f. IMBLMS Functional Breadboard Performance Review, Phase B-3, General Electric Company, December 1969.

g. IMBLMS FBB - Phase B-3 - Final Summary Report, General Electric Company, February 1970.

h. IMBLMS Phase B3 - Functional Breadboard, Final Summary Report, LMSC-A963878, Lockheed Missiles and Space Company, February 1970.

i. Statement of Work, IMBLMS Phase B4.

j. Proceedings on the Winter Study on Uses of Manned Space Flight, 1975 - 1985, NASA Science and Technology Advisory Committee for Manned Space Flight, NASA SP-196, December 1968.

7.4.1.3 The Effects of the Spaceflight Environment on Psychomotor Functions

7.4.1.3.1 Scientific or Technical Objectives. These experiments, a portion of the Behavioral Effects class of experiments, have as their objective the determination of the effects of long-duration space flight on man's psychomotor functions.

7.4.1.3.2 Description. The experiments designed to evaluate the status of man's psychomotor functions will utilize the psychomotor console from the Behavioral Measurements Unit and the video tape cameras and recording equipment from the Visual Records and Microscopy Unit. In addition, it will use one item of experiment-peculiar equipment, an item similar to the AAP Task Board, for measuring limb strength and arm-leg control of force.

The experiments require measurement of psychomotor parameters for each subject periodically throughout the mission. Subjects will be seated at the console or AAP task board and administer to themselves the test sequence by activating the computer-controlled program and the data-gathering apparatus.

7.4.1.3.3 Observation/Measurement Program. Psychomotor parameters that will be measured, their description, measurement units, and range in significant digits are indicated in Table 7-9.

The limb strength parameter has been suggested in addition to the basic psychomotor tests due to the importance of such data in design applications. It is estimated that approximately ten responses will be required from the test subject for each of the six parameters. Each measurement session is estimated not to exceed 120 min/subject and will be repeated every 10 days during the initial mission. Any testing session may be interrupted for emergency requirements, or the schedule can be varied to fit other needs. An interruption will impose a requirement for a repetition of the interrupted measurements.

Table 7-9. Psychomotor Measurements

PSYCHOMOTOR PARAMETER	DESCRIPTION	UNITS IN WHICH MEASURED	RANGE (SIG. DIGITS)
Fine Motor Abilities	Steadiness of hand and arm measured in terms of frequency and amplitude of hand-arm movements in three directions.	Frequency and amplitude of hand-arm movements in pitch, roll, yaw.	Freq.: 2 digits Amplitude: 2 digits
Complex Motor Abilities	Ability to perform simultaneously two or more tasks, each requiring a high degree of perceptual-motor coordination, measured in time and errors.	Time in seconds Errors (discrete count)	Time: 2 digits Errors: 2 digits
Gross Body Coordination	Ability to coordinate simultaneous action of different body parts as in locomotion and donning of pressure suit, measured in time and errors.	Time in seconds Errors	Time: 2 digits Errors: 2 digits
Limb Strength, Arm-Leg Control of Force	Time and accuracy in attaining and holding prescribed high and low level forces.	Newtons of force attained; time in seconds to attain it; time in seconds holding it.	Force: 3 sig. digits Time: 3 sig. digits
Reaction Time, Simple and Complex	Speed and accuracy in responding to a single stimulus (simple RT) and to a progressive increase in informational load (complex RT) using visual and auditory stimuli.	Time ranges from hundredths of a second to 100 seconds. Error is a discrete count.	Time: 4 sig. digits Error: 2 sig. digits
Tracking, Pursuit and Compensatory	Error scores over time using a joystick to track a display on a CRT.	Frequency and amplitude of error over time.	Time: 2 sig. digits Error: 2 sig. digits

Information on environmental variables is required for study of cause-effect relationships for any changes observed. Minor random accelerations generally will not affect measurements. Larger accelerations will require a rerun of the affected measurement.

7.4.1.3.4 Interface, Support, and Performance Requirements. The psychomotor experiments will be conducted in the normal pressure, temperature and zero-g environment of the spacecraft. They will not be affected by the vehicle parameters such as orbit altitude, pointing requirements, etc. Power requirements are estimated to be a maximum of 150 watts with an average of 100 watts. The data output varies from cine film or video tape recordings to computer-stored outputs of task time, error, and strength data.

7.4.1.3.5 Potential Role of Man. The crew will be essential participants in the experiment. As test subjects they will require no special skills other than thorough familiarization with all experiment equipment and procedures. While the experiments can be self-administered, an electromechanical technician trained in the Behavioral Measurements Unit should be available for experiment preparation, termination and maintenance activities.

7.4.1.3.6 Available Background Data

a. The "Psychomotor" experiment in Manned Space Flight Capability, Part 1 of 2 (Biomedicine, Behavioral, Man-Machine Integration), Earth Orbital Experiment Program and Requirements Study, McDonnell-Douglas Astronautics Company.

b. The "Psychomotor Capabilities in Zero-g and Partial g" experiment in Requirements Study for a Biotechnology Laboratory for Manned Earth-Orbiting Missions - Phase II, McDonnell Douglas Astronautics Company, MDC G0620, July 1970.

c. The "Psychomotor Functions" experiment in Requirements Study for a Biotechnology Laboratory for Manned Earth-Orbiting Missions, NASA CR-1408, Volume I, August 1969.

d. The "Psychomotor Functions" experiment in Requirements Study for a Biotechnology Laboratory for Manned Earth-Orbiting Missions, NASA CR-1409, Volume II, August 1969.

e. The "Behavioral Effects" experiment in Experiment Data Book - Space Station Program, General Electric Company, EL-103, Revision C, 12 June 1970.

f. IMBLMS Functional Breadboard Performance Review, Phase B-3, General Electric Company, December 1969.

g. IMBLMS FBB - Phase B-3 - Final Summary Report, General Electric Company, February 1970.

h. IMBLMS Phase B3 - Functional Breadboard, Final Summary Report, LMSC-A963878, Lockheed Missiles and Space Company, February 1970.

i. Statement of Work, IMBLMS Phase B4.

7.4.1.4 Effects of the Spaceflight Environment on Individual and Group Dynamics. The remainder of the Behavioral Effects class of experiments are grouped as Individual and Group Dynamics experiments.

As stated in the NASA Long Range Plan for Aerospace Medicine, "during extended missions, with more diverse activities in space, the characteristics of the individuals and the dynamic interactions of the various crew members can become critical to the safety and successful accomplishment of the mission." From the beginnings of the National Space Program, concern has been expressed by the scientific community about the potentially detrimental influence of space flight on individual and group behavior. The eminently successful space flights to date, with small crews and short missions, has neither confirmed nor allayed these concerns.

The present base of knowledge regarding group behavior under stress comes mainly from three sources: 1) the literature on ship wrecks and disasters, expeditions, remote duty stations, Navy ships and submarines, prisoner of war camps, and mental hospitals, which stresses the influence of isolation and confinement; 2) small-group

research literature which is rich in theory and experimental technique; and 3) research with confined crews, specifically aimed at simulating space conditions, which includes efforts by government agencies, universities, and industry. Additional contributions come from the research on extreme confinement and social deprivation, research on military groups such as bomber crews, and personnel psychology research with industrial groups.

Researchers in general agree that long-term isolation and confinement results in 1) time-phased stages of group behavior characterized by differences in work performance, emotional problems, and general activity; 2) degradation of perceptual, motor, and certain intellectual skills; 3) interpersonal conflict; 4) status leveling; 5) acceleration of interpersonal exchange; 6) monotony and boredom; and 7) degraded social-emotional well-being. The effects on mission success of these factors, interacting with the additional stresses of the spaceflight environment, need to be determined and corrective procedures identified.

7.4.1.4.1 Scientific or Technical Objectives. Objectives of these experiments are to:

a. Determine the effect of extended spaceflight on man's personal and social behavior.

b. Determine the effect of extended spaceflight on group processes, structure, attitudes and productiveness.

c. Identify individual characteristics and crew compositions and structures which are predictive of successful adaptation to the conditions of extended spaceflight.

d. Develop and evaluate preventive training and therapeutic techniques.

7.4.1.4.2 Description. These experiments require periodic sampling of individual and group behavior over the course of the mission. To obtain uncontaminated measures, this requires controlled unobtrusive observations of crew members during normal missions, experimental, and off-duty activities as well as the use of traditional subjective questionnaires and clinical interview assessments during flight.

Equipment requirements will primarily come from the Visual Records and Microscopy Unit of the CORE and will consist of cine film or video tape cameras and recorders augmented by audio tape recorders for unobtrusive monitoring of crew activities. The remotely controlled video cameras will have a frame frequency adjustable from 30 fps to 1 frame every 3 seconds, a time reference recording capability, and a zoom lens (12-60 mm). GSR and EEG equipment will be utilized during the personal interview sessions. While it is desirable for an onboard observer to conduct these interviews, they would be subject to the same stresses as their interviewees and would be prone to lose their objectivity. Therefore, experiment-peculiar equipment will be necessary in the form of a private space/ground communications channel to conduct these sessions, as well as a private area, approximately 1.5 × 2.4 × 2.1 m (5×8×7 ft),

aboard the spacecraft. This private channel would be used as a therapeutic technique as well as a data-gathering device in that individual crew members could periodically speak with their families, etc. This channel would allow real-time sampling of individual behavior.

7.4.1.4.3 Observation/Measurement Program. The parameters of interest, their description, units, ranges, etc., are listed in Tables 7-10 and 7-11. They will be referenced to preflight baseline measurements of each crew member and crew unit. Any measurement session may be interrupted; the data would be discarded and measurements taken anew at the next opportunity.

7.4.1.4.4 Interface, Support, and Performance Requirements. These experiments will be conducted within the normal environmental limits of habitable areas of the spacecraft due to the nature of the investigation which requires correlation to the normal environment.

Power requirements are estimated to be a maximum of 400 watts with an average requirement of 200 watts.

Data output will consist of magnetic tape containing video and audio data with time reference, 750 m (2400 ft) per 90 days; computer-stored questionnaire responses with time and crewman reference, and telemetry of significant physiological parameters.

7.4.1.4.5 Potential Role of Man. The crew will be essential participants in the experiment, both as subjects and as experimenters. As subjects, all crewmen will participate during their normal daily activities, and while responding to the questionnaires and interview sessions on an average of 70 minutes per crewman per week. No special skills will be required other than the normal familiarization with all experiment equipment and procedures. As experimenters, they will relocate and adjust cameras, lighting, and recorders as necessary, replenish magnetic tape, and package, label, and store data for ground transmittal. They will also be responsible for initial setup and checkout, routine maintenance, and termination of the experiment and its equipment. Two electromechanical technicians will be required.

7.4.1.4.6 Available Background Data.

a. The "Group Dynamics" and "Personal and Social Adjustment" experiments in Manned Space Flight Capability, Part 1 and 2 (Biomedicine, Behavioral, Man-Machine Integration), Earth Orbital Experiment Program and Requirements Study, McDonnell Douglas Astronuatics Co.

b. The "Personal and Social Adjustment" and "Effects of Spaceflight on Crew Structure and Group Behavior" experiments in Requirements Study for a Biotechnology Laboratory for Manned Earth-Orbiting Missions - Phase II, McDonnell Douglas Astronautics Company, MDC G0620, July 1970.

Table 7-10. Group Measurements

Parameters	Description	Units in Which Measured	Range of Measurements	Required Accuracies in Measurements
1. Crew Productivity	Task time and errors for selected tasks (min. of five tasks)	1. Seconds to perform task. 2. Number of task elements omitted or performed out of order. 3. Percent error in performance.	Task times - 120 to 900 sec Task elements - 0-100 Errors - 0-100%	±10% for total task; →0% for subelements.
2. Verbal Interaction	Subjective categorization of verbal behavior	Single segments of verbal behavior classifiable into discrete categories	12-15 point scale ranging from negative (destructive of group integration) through neutral to positive (conducive to group integration)	Placement of interactions in categories is a subjective judgment of trained observer.
3. Physical Interaction		1. Physical location of crewman with relation to each other. 2. Individual crewman activity.	1. Maximum of 20 predetermined locations within spacecraft. 2. Maximum of 20 predetermined activities (e.g. mission tasks, personal hygiene, sleeping, etc.)	Must be capable of being reliably placed in appropriate categories.
4. Crew Mood	Subjective feelings and attitude of crewman	Points on a rating scale above or below a neutral point.	7-point scale from very low to very high on specific attributes	Should have a high correlation (.85-.95) with independent measures of same attributes.

Table 7-10. Group Measurements (contd)

Parameters	Pattern of Change	Duration per Measurement	Time Between Measurements	Number of Measurements	Total Measurement Period
1. Crew Productivity	Decrease in task time and errors for first few days followed by possible increase as mission duration increases	2-15 min for each task	10 days for each task	15 measurements per 30 days (since min. of 5 tasks is necessary)	30-225 minutes per 30 days
2. Verbal Interaction	Number and quality will vary as a function of changes in group structure	4 hours per measurement period	10 days	3 measurement periods each 30 days	12 hours each 30 days
3. Physical Interaction	Individuals may exhibit more physical detachment and withdrawal from group with time	4 hours per measurement period	10 days	3 measurement periods each 30 days	12 hours each 30 days
4. Crew Mood	Will change over time as a function of feelings of group acceptance, self concept of success in group participation, and his estimate of mission hazards and success potential	5 minutes to 30 minutes	10 days	3 measurement periods each 30 days	15 minutes to 90 minutes each 30 days

Table 7-11. Individual Measurements

Parameters	Description	Units in Which Measured	Range Signif. Digits
Test Results, Objective & Projective			
Individual personality traits	Acquisitiveness, Conservatism, Masculinity, etc.	Raw/normative scores	2
Group-oriented personality traits	Aggressiveness, gregariousness	" " "	2
Society-oriented personality traits	Altruism, patriotism, service	" " "	2
GSR	Skin resistance measurement	0-100 kilohms	3
EEG	Brain potentials, in complex, nonperiodic waveform	Frequency — 0-30 Hz Amplitude — 0-200 microvolts	2 3
Verbal Behavior	Identity with group, agressive vs withdrawal	Daily word output pronouns	3
Observation Records	Use of recreation facilities, sick call, sleep patterns		
Questionnaire Results	Peer ratings, spacecraft habitability ratings mission/program attitudes		

Total measurement session requires approximately 10 minutes per week per crewman, plus additional non-interference testing for a total of one hour per week per crewman.

c. The "Intrapersonal Factors" and "Interpersonal Factors" experiments in Requirements Study for a Biotechnology Laboratory for Manned Earth-Orbiting Missions, NASA CR-1408, Volume I, August 1969.

d. The "Intrapersonal Factors" and "Interpersonal Factors" experiments in Requirements Study for a Biotechnology Laboratory for Manned Earth-Orbiting Missions, NASA CR-1409, Volume II, August 1969.

e. The "Behavioral Effects" experiment in Experiment Data Book – Space Station Program, General Electric Company, EL-103, Revision C, 12 June 1970.

f. Proceedings on the Winter Study on Uses of Manned Space Flight, 1975-1985, NASA Science and Technology Advisory Committee for Manned Space Flight, NASA SP-196, December 1968.

7.4.2 PERFORMANCE CAPABILITY ASSESSMENT

7.4.2.1 Cargo-Handling Capabilities. These experiments are a portion of the Performance Capability Assessment class of experiments.

7.4.2.1.1 Scientific or Technical Objectives. To establish the limits of the crew's ability to manipulate and transfer various mass sizes and configurations by using mechanical aids, restraint, and tether devices and to develop and evaluate cargo-handling procedures, training requirements, and metabolic costs.

7.4.2.1.2 Description. Man's capability to transfer, handle, and store containerized cargo, fluids, and large pieces of equipment will be evaluated for a variety of techniques and support aids. Cargo of different sizes, shapes, masses, and consistencies will be unstowed, manipulated, transferred, and restowed by the test subjects using various mechanical aids, rails, cables, umbilicals, handholds, etc., during both EVA and IVA.

Support equipment will be required from the MSI Mobility Unit and Airlock/EVA Capability Unit as well as from the Visual Records and Microscopy Unit of the CORE. The Mobility Unit will provide 1) a portable metabolic rate analyzer for measuring and transmitting crew metabolic rates, 2) portable acceleration sensors for sensing and transmitting positive and negative accelerative forces without interference with mass motion, 3) a timer for recording task times and 4) the selected locomotion and restraint devices. The Airlock/EVA Capability Unit will provide the equipment and facilities such as airlocks, pressure suits, EVA viewing ports, tether control units, communications, etc., to allow EVA testing. The Visual Records units will provide motion picture or video tape coverage of the experiments. The tape will identify the task, subject, time, location, and be in sync with other cameras that are recording the same event. Experiment-peculiar equipment will include the test masses [total approximately 369 kg (800 lb) occupying 0.35 m^3 (12.5 ft^3)], and the mechanical aids, umbilicals and other experimental cargo transfer aids to be tested.

7.4.2.1.3 Observation/Measurement Program. The primary measurements include 1) the time to complete the cargo-handling task, 2) the level of energy expended, 3) the number and type of errors committed (damaged or lost cargo, etc.), 4) mass motion and accelerations, and 5) crew subjective opinions. The measurement period is estimated to require 1.5 hours, 10 times a month.

7.4.2.1.4 Interface, Support, and Performance Requirements. Gravitational, vibrational, contamination, atmospheric, thermal, and radiation environmental limits will be the same as spacecraft nominal for IVA testing due to the nature of the investigation. Pulsating g-levels will affect performance of the experimental task.

Data physical formats will include digital or analog signals from the metabolic analyzer and the acceleration sensor transmitters. Video tape and subjective opinions will also be recorded. All data will be event-time keyed as to specific experiment, run number, and subject.

Power will be required for the motion picture or TV coverage, lighting systems, and EVA systems, but not for the portable transmitter which will be battery powered. An average of 220 watts is estimated.

7.4.2.1.5 Potential Role of Man. Man will be an essential participant in the experiment as subject and as experimenter. As a test subject, with no special skill requirements, he will be required to perform all experimental tasks. As experimenter, he will be required to set up and check out the cargo-handling apparatus, prepare spacecraft and support equipment for operations, brief the subject, conduct test protocol, debrief the subject, and stow all materials. The skills of a behavioral scientist will be required.

7.4.2.1.6 Available Background Data

a. The "Space Logistics and Resupply" experiment in Manned Flight Capability, Earth Orbital Experiment Program and Requirements Study, McDonnell-Douglas Astronautics Co.

b. The "Cargo-handling Capabilities" experiment in Requirements Study for a Biotechnology Laboratory for Manned Earth-Orbiting Missions - Phase II, McDonnell-Douglas Astronautics Co. MDC G0620, July 1970.

c. The "Mass Translation" experiment in Requirements Study for a Biotechnology Laboratory for Manned Earth-Orbiting Missions, NASA CR-1408, Volume I, August 1969.

d. The "Mass Translation" experiment in Requirements Study for a Biotechnology Laboratory for Manned Earth Orbiting Missions, NASA CR-1409, Volume II, August 1969.

e. The "Bulk Material Handling" experiment in Experiment Data Book — Space Station Program, General Electric Company, EL-103, Revision C, 12 June 1970.

7.4.2.2 Assembly, Deployment, Maintenance, and Repair Capabilities. A typical experiment from this group, a part of the Performance Capability Assessment class of experiments, is discussed below as an example: EVA Maintenance and Repair of Reaction Control Systems.

7.4.2.2.1 Technical Objectives. To evaluate, under actual spaceflight EVA conditions, the repair and maintainability of an Attitude Control Propulsion System.

7.4.2.2.2 Description. One or more reaction control systems using high-temperature gas jets will probably be used to help control the Space Station attitude and orbit radius, and to overcome atmospheric drag. These systems may also be used to maneuver prior to docking with another spacecraft. Attitude and drag control may be accomplished by very small thrust engines which could, for example, use electrically heated gases and vapors from Space Station waste products. Larger engines may use either monopropellants or bipropellants with the main emphasis on propellant storability and cleanliness of the exhaust products (that is, exhaust products which will form minimum harmful deposits on the exterior of the spacecraft and its related equipment).

Obviously, these rocket engines will be designed for high reliability over a long period. However, it may not be possible to obtain the necessary life or reliability, and repairs or replacement of parts or subassemblies must be a part of the anticipated maintenance activities. In particular, thrust nozzles, valving or other control components may have to be replaced. A sketch of the proposed system is shown in Figure 7-7.

In this experiment, actual replacement of a thrust module subassembly or of critical components (such as the thrust nozzle or a valve) will be conducted under EVA conditions. This could be done with an actual RCS unit or with a dummy unit. With

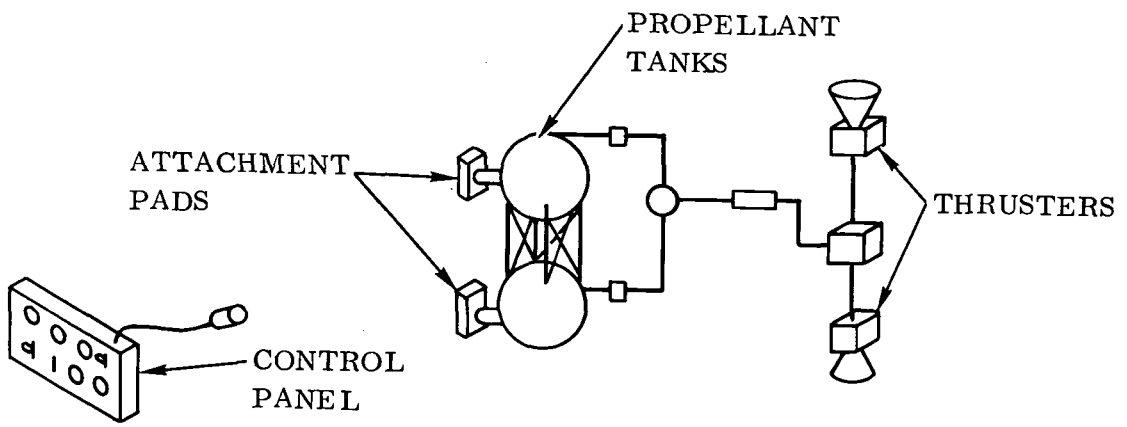


Figure 7-7. Maintainable Attitude Control Propulsion System

an "in-use" system utilizing liquid propellants, the feed line cannot be parted or opened without depressurization and purging to remove excess propellant (if required). To reduce complexity and increase reliability, manual shutoff valves may be considered which would require EVA manipulation. Removal of components will require EVA manipulation and special wrenches and possibly other tools. The astronaut will also have to use body restraints, such as straps or a cage-type enclosure, in order to exert certain forces and torques while working.

Established procedures for repairing the RCS will be evaluated and possibly revised as a result of this experiment. The final evaluation will decide on the adequacy of tools, body restraints, and hardware arrangement relative to replacing RCS parts or subassemblies. Familiarity with EVA maintenance will be obtained by the participating astronauts so that enforced repairs may be completed with satisfactory foreknowledge of the time required and possible problem areas.

The maintenance activities should be observed by a trained-time-and-motion analyst, either directly or through a remote TV camera. Performance of the astronauts will be noted through time to complete the assigned tasks, wasted motion, ease of manipulating tools and parts, etc.

In addition to the EVA maintenance activities, IVA maintenance should be investigated to study possible problems related to toxic liquids and gases within the maintenance area and the cleaning of the RCS assemblies and components. A general purpose workshop area would suffice for the IVA studies, providing adequate protection from the RCS liquids and gases can be given to equipment and crew.

7.4.2.2.3 Observation/Measurement Program: Observations and measurements to be made are:

a. Time to complete a specified task.

b. Physical movements of astronaut during the maintenance and/or repair activity.

The activities to be accomplished in a typical activity are:

a. Prepare tools, replacement part(s), and body restraints.

b. Prepare camera and related equipment.

c. Prepare EVA suit and life support pack.

d. Put on suit, attach tools, hardware, and camera.

e. Exit spacecraft through airlock.

f. Mount camera on spacecraft skin so that working area is covered. (This step is omitted if work area can be viewed from window.)

g. Attach body restraint harness (or cage) at work site.

h. Proceed with maintenance operations.

i. Detach body restraints, camera, etc., and return into spacecraft through airlock.

Steps f through i are monitored by a time and motion analyst. Times to accomplish subtasks are recorded, as are wasted motion, difficulty in manipulating tools, hardware, etc. Continuing voice contact between the astronaut performing EVA maintenance and the time/motion analyst is essential. Subtasks to be evaluated will be established prior to experiment. Experiment results will be evaluated as soon as possible after the maintenance task, so that obvious procedure changes can be incorporated into subsequent steps of the experiment.

7.4.2.2.4 Interface, Support and Performance Requirements. One crew member will be required to accomplish the various phases of the experiment in an EVA environment. Another crew member will be required to film the EVA activities and ensure that the EVA voice comments are properly recorded. Following each phase of the experiment, a critique of the operations must be conducted to determine if any procedural changes should be made which would affect the following phases of the experiment.

It is anticipated that about 400 watts of power will be required for the TV camera/recorder and 50 watts for the cine film camera. In addition, about 500 watts of power would be needed for artificial illumination if the experiment is accomplished out of direct sunlight.

No specific pointing requirements exist, except that some of the experiment phases should be accomplished in direct sunlight and some in Earth shadow so as to evaluate the relative difficulty of working under various illumination levels. No stabilization requirements exist, except that the EVA astronaut should be warned prior to significant attitude changes to preclude accidental loss of experiment tools or components.

No requirements for thermal control exist.

If the time and motion data are taken via a sound-on-film cine camera, then delivery of approximately 10 rolls of film weighing 10 kg (22 lb) is anticipated. If data is recorded on video tape, it could be telemetered to ground stations for recording and subsequent analysis.

The standard space station EVA environments are required to support the conduct of the experiment. The film or TV camera may have to be mounted on the outside of the Space Station if a viewport is not available for filming the experiment activity. A standard EVA airlock must be provided. A mounting base for the experimental RCS module is needed. Restraint-strap mountings must also be located adjacent to the experimental area.

No special prelaunch requirements exist.

Some perturbations to the Station attitude can be expected due to the EVA activity. In addition, occasional venting of propellants and operation of the RCS experimental thruster will induce torques to the station.

Interface and support requirements are summarized below:

Crew Support	One EVA astronaut, one astronaut filming for 10 repair excursions	
Communication	Standard EVA with recording	
Size	Experimental RCS	36 x 36 x 36 cm (14 x 14 x 14 in)
	Camera	30 x 15 x 10 cm (12 x 6 x 4 in)
	Tools	30 x 8 x 8 cm (12 x 3 x 3 in)
Weight	Experimental RCS	23 kg (50 lb)
	Camera	5 kg (10 lb)
	Tools	2.5 kg (5 lb)
Power	Camera - 400 watts; Lights - 500 watts	
Pointing	No requirement	
Stabilization	No requirement - Warning to EVA crew if stabilization movements to occur	
Thermal Control	None	
Data Return	Movie film or video data link	
Unique Environments	Standard EVA suit environment	
Prelaunch	No requirements	
Torque Outputs	Some minor torques	

7.4.2.2.5 Potential Role of Man. This experiment requires that man function in an active role since his ability to perform various EVA operations is an integral part of the experiment. Crew skills required for the EVA activities are those of an electro-mechanical technician. The camera operator would require the skills of a photo technician.

7.4.2.2.6 Available Background Data

a. The "EVA Maintenance and Repair of Reaction Control Systems," the "Maintenance and Repair of Thermal Control Coatings," and the "Maintenance, Repair and Retrofit Generalized Experiments" experiments in Manned Space Flight Capability, Earth Orbital Experiment Program and Requirements Study, McDonnell-Douglas Astronautics Co.

b. The "Maintenance Activities and Tool Evaluation" experiments in Requirements Study for a Biotechnology Laboratory for Manned Earth-Orbiting Missions - Phase II, McDonnell-Douglas Astronautics Company, MDC G0620, July 1970.

c. The "Accessibility" experiment in Requirements Study for a Biotechnology Laboratory for Manned Earth-Orbiting Missions, NASA CR-1408, Volume I, August 1969.

d. The "Accessibility" experiment in Requirements Study for a Biotechnology Laboratory for Manned Earth-Orbiting Missions, NASA CR-1409, Volume II, August 1969.

e. The "Maintenance Operations Techniques" experiment in Experiment Data Book - Space Station Program, General Electric Company, EL-103, Revision C, 12 June 1970.

f. The "Investigation of zero g Repair and Maintenance of Free-Floating Satellites," the "Investigation of Zero g Removal and Replacement of an RCS Engine," and the "Study of Zero g Manual Alignment and Pointing of Large Optical Systems" experiments in NASA Long Range Plan for Aerospace Medicine, 15 June 1969.

g. Proceedings of the Winter Study on Uses of Manned Space Flight, 1975 - 1985, NASA Science and Technology Advisory Committee for Manned Space Flight, NASA SP-106, December 1968.

7.4.2.3 Locomotion and Restraint Capabilities

7.4.2.3.1 Scientific or Technical Objectives. This group of experiments within the Performance Capability Assessment class will develop and evaluate locomotion and restraint devices and techniques for their optimum utilization by man in space.

7.4.2.3.2 Description. Experiments will be performed in space while utilizing specific locomotion and restraint devices and instrumentation contained in the MSI Mobility Unit. By varying the combinations of locomotion and restraint possibilities and known crew tasks, it will be possible to achieve quantifiable result data. The following Mobility Unit equipment will be required:

a. Portable metabolic rate analyzer. The portable man-mounted metabolic analyzer will analyze and transmit the results while the experiment is being conducted. The resultant curve will then be compared to the time, type of locomotion aid or restraint or their combination, and task performance as a means of total or partial experiment results.

b. Impact force recorders. The force or pressures created by the crewman while performing specific tasks will be recorded on a predesignated basis. In general, pickoff points will be fixed on tether, locomotion aids (handrails, grip aids, etc.), and restraint aids (pelvic restraints, toe holds, etc.). Other points will be located on the floor, wall and ceiling panels that are instrumented to record force

or pressure application. Torque or rotational force loads will be recorded as required for items as handholds, handrails, handles and knobs that have man-generated rotational forces imposed upon them.

c. Acceleration recorders. Acceleration pickups will have to be developed that are capable of being man-mounted. These pickups will be capable of sending a signal, upon activation, to a man-mounted transmitter or capable of transmitting directly. The acceleration pickups will be capable of defining between positive and negative acceleration forces.

d. Elapsed timer. All designated tasks will be timed from a start and stop point that will be predetermined.

Time-lapse TV support equipment from the Visual Records Unit will be required for record-keeping. The tape will identify the task, subject, time, location and be in sync with other TV cameras that are recording the same event. Real-time TV recording will be available upon demand for specific tasks. The Airlock/EVA Capability Unit will also be utilized during EVA evaluations.

7.4.2.3.3 Observation/Measurement Program. Basic measurements and their respective ranges, accuracies, units of measure, etc., are listed in Table 7-12. The primary measurements for each locomotion aid, restraint device, mobility technique, etc., will be crewman metabolic rate, force-generation, body accelerations, and task completion time. These measurements will be augmented by visual records and subjective evaluations.

7.4.2.3.4 Interface, Support, and Performance Requirements. Gravitational, vibrational, contamination, atmospheric, thermal and radiation environmental limits will be the same as spacecraft nominal due to the nature of the investigation which must be correlated to nominal spacecraft environments. Pulsating g-levels will affect the performance of the experimental task. The experiments will not be affected by orbit altitude, inclination, magnetic field, pointing requirements, etc.

Data physical formats will include digital or analog signal from impact pickups, the metabolic analyzer, and the acceleration-detector transmitters. In addition, time-lapse TV coverage and subjective opinions will be recorded. All data will be event-time keyed as to specific experiment, run number, and subject.

Power will be required for the force transducers, TV coverage, and lighting systems, but not for the portable transmitters as they will be battery powered.

7.4.2.3.5 Potential Role of Man. The crew will be essential participants in the experiment, both as experimenters and as test subjects. As experimenters, they will be required to perform the following activities:

Onboard Preparation: Fit portable equipment to subjects, check out transmitters and recording equipment, arrange programmed combination of

Table 7-12. Locomotion and Restraint Measurement Program

Name of Measurement	1. Metabolic Rate	2. Impact	3. Accelerations	4. Task Duration	5. Crew Questionnaire and Visual Records
Units	Joules/sec (kcal/min)	m-N (ft-lb)	g	minutes	NA
Measurement Range	70 to 2100 (1 to 30)	0.1 to 300 (0.075 to 220)	0.1 to 10 g (pos. & neg.)	0 to 4 hr ± 1.0 sec.	NA
Reqd Accuracy	±0.1	±0.1	±0.1	±1.0 sec.	Subjective
Pattern of Change	An increase as work level increases and more energy is expended.	Increase and decrease in pattern with specific technique being used.	Same as 2	Will change with learning curve and subject.	NA
Reference or Control	One-g ground run-through of each task will be utilized to establish a norm.	Same as 1	Same as 1	Same as 1	NA
Phenomenon Lifetime	Duration of Experiment	Same as 1	Same as 1	Same as 1	Same as 1
Measurement Duration	One analysis and readout per breath (inhale/exhale)	For pulse of impact	Duration of experiment	Same as 3	NA
Time Between Measurements	Breath to breath	Random	Continuous measurement	Same as 3	NA
Number of Measurements	One per breath for duration of experiment	One for each impact	One per sensor	One	NA
Total Measurement Period	Duration of experiment task	Same as 1	Same as 1	Same as 1	NA
Interrupt or Vary Schedule	No, it would invalidate the recording	No	No	No, a break would give a false readout	No, must be continuous to provide results for complete analysis
Time from Mission Start	After experiment setup	Same as 1	Same as 1	Same as 1	NA
Disturbance Affecting Measurement	Pulsating g-levels in spacecraft	Same as 1	Same as 1	--	--

	locomotion and/or restraint devices, and check out TV cameras for proper alignment and adjustment.
Experimental Equipment Operation:	Activate transmitters and recorders to initiate experimental run; monitor recording equipment to assure that the transmitted data is being received and recorded.
Adjustments and Modifications:	Perform equipment adjustments as necessary, deactivate and stow equipment after a run, provide scientific assessment of intermediate results, and store data for transmittal to ground.
Terminal Activity:	Terminate experiment equipment after final runs.

Two crewmen will be required to prepare and terminate the experiment with one serving as an experiment monitor. Electromechanical technicians are required under the supervision of a behavioral scientist.

As subjects, the crew will perform all experimental tasks as programmed and record their observations and subjective opinions in the crew log. A minimum of six subjects should perform the experiment. No specific crew skills will be required of the subjects other than complete familiarization with all experimental equipment and procedures.

7.4.2.3.6 Available Background Data:

a. The "Locomotion and Restraint" experiment in Manned Space Flight Capability, Part 1 of 2 (Biomedicine, Behavioral, Man-Machine Integration), Earth Orbital Experiment Program and Requirements Study, McDonnell-Douglas Astronautics Co.

b. The "Evaluation of Locomotion Techniques and Aids" experiment in Requirements Study for a Biotechnology Laboratory for Manned Earth-Orbiting Missions - Phase II, McDonnell-Douglas Astronautics Company, MDC G0620, July 1970.

c. The "Personnel Translation" and the "Orientation, Stability, and Restraint" experiments in Requirements Study for a Biotechnology Laboratory for Manned Earth-Orbiting Missions, NASA CR-1408, Volume I, August 1969.

d. The "Personnel Translation" and the "Orientation, Stability, and Restraint" experiments in Requirements Study for a Biotechnology Laboratory for Manned Earth-Orbiting Missions, NASA CR-1409, Volume II, August 1969.

e. The "Bulk Material Handling" experiment in Experiment Data Book - Space Station Program, General Electric Company, EL-103, Revision C, 12 June 1970.

f. The "Study of IVA Locomotion Aids" and the "Weightless Mobility Aids" experiments in NASA Long Range Plan for Aerospace Medicine, 15 June 1969.

g. Proceedings of the Winter Study on Uses of Manned Space Flight, 1975-1985, NASA Science and Technology Advisory Committee for Manned Space Flight, NASA SP-196, December 1968.

7.4.2.4 System Controller Capabilities. These experiments, the remainder of the Performance Capability Assessment class, have been grouped under the title System Controller Capabilities. A variety of experiments have been proposed in this area, such as Data Handling Capabilities, Advanced Controls/Displays, Evaluation of Computer-Generated Electronic Displays, Technical Data Storage and Retrieval, Communications and Recording, Monitoring and Observation, Operator Autonomy Studies, Control Display System Studies, and Information Display and Processing. A typical experiment from this group, Communications and Recording, has been outlined and is discussed below.

7.4.2.4.1 Scientific or Technical Objectives. To evaluate the crew's ability to communicate information and record data as a function of exposure to orbital stresses.

7.4.2.4.2 Description. The following materials and equipment requirements have been identified:

a. Audio recorders

b. CRT and other information displays

c. Information display associated controls

d. Cameras (cine, still, and/or TV) and lights

e. Timer

f. Paper and pen tests

g. Log book

h. Questionnaires.

The audio tape recorders will have to be able to record voices over a range of 200 to 9000 Hz and 10 to 110 dB. Mission time will be automatically put on tape when activated by voice or push-to-talk switch. A noise-cancelling mike, voice-activated with minimum delay and 2-sec followup is desired.

The CRT displays will be a minimum of 10 to 13 cm (4 to 5 in) in diameter, capable of dual input for target and cursor, and with 15 x 15 cm (6 x 6 in.) grid projections, and alphanumeric displays.

The cameras, paper and pen tests, log book, and questionnaire are part of the Visual Records and Microscopy Unit of the CORE.

The experiment, with the major proportion of the data being automatically recorded, will be conducted for 15 minutes at 21-day intervals. The primary equipment may be integrated with the normal spacecraft control-display instrumentation.

7.4.2.4.3 Observation/Measurement Program. The following measurements and observations will be recorded:

a. Dexterity

b. Manipulation

c. Event Record

d. Voice Record

e. Control/display dynamics

f. Time

g. Subjective Opinion (Standardized questionnaires must be developed).

7.4.2.4.4 Interface, Support, and Performance Requirements. Gravitational, vibrational, contamination, atmospheric, thermal, and radiation environment limits will be the same as spacecraft nominal due to the nature of the investigation which must be correlated to nominal spacecraft environments. The experiments are estimated to require an average of 225 watts of power, 43 kg (95 lb) of equipment, and occupy a 0.2 m^3 (7 ft^3) volume.

7.4.2.4.5 Potential Role of Man. The crew will be essential participants in the experiment both as test subjects and experimenters. One crew member, with no specific skill requirements except knowledge of the experimental procedures and equipment operation, will perform the test, while a second crew member will act as an observer and event recorder. He should possess the skill of a behavioral scientist.

7.4.2.4.6 Available Background Data.

a. Requirements Study for a Biotechnology Laboratory for Manned Earth-Orbiting Missions - Phase II, McDonnell-Douglas Astronautics Company, MDC G0620, July 1970.

b. Requirements Study for a Biotechnology Laboratory for Manned Earth-Orbiting Missions, NASA CR-1408, Volume I, August 1969.

c. Requirements Study for a Biotechnology Laboratory for Manned Earth-Orbiting Missions, NASA CR 1409, Volume II, August 1969.

d. Experiment Data Book - Space Station Program, General Electric Company, EL-103, Revision C, 12 June 1970.

e. Proceedings of the Winter Study on Uses of Manned Space Flight, 1975 - 1985, NASA Science and Technology Advisory Committee for Manned Space Flight, NASA SP-196, December 1968.

7.4.3 HABITABILITY AND PROFICIENCY MAINTENANCE

7.4.3.1 Interior Configurations, Environments, and Decor

7.4.3.1.1 Scientific or Technical Objectives. This group of experiments, part of the Habitability and Proficiency Maintenance class of experiments, will develop and evaluate space vehicle features that provide the most habitable design for crew living and working areas in long-duration space flight. Features under consideration include crew area, volume, configuration, layout, privacy provisions, illumination, noise, temperature, decor, and color. The criteria derived from these experiments will enable designers to plan and implement future spacecraft interiors for habitability with predictable results.

7.4.3.1.2 Description. Interior configurations, environments, and decor will be evaluated by analyzing their effect on three crew parameters: 1) physical health, 2) work efficiency, and 3) crew attitude and motivation. Measurements of each of the three parameters will be correlated with controlled interior changes to identify optimum configurations.

The entire habitable areas of the spacecraft will be required for the experiments. Equipment required to support the experiments consists primarily of constant-duty time-lapse TV cameras from the Visual Records and Microscopy Unit of the CORE. All habitable areas will be monitored on a 24-hour basis. Movement patterns and activities of the crewmen will be recorded on a time-lapse basis and dumped on demand, or as programmed, for ground analysis. All data will be identified by time and location of recording. Time-lapse TV will be activated by occupancy of a habitable area by a crewman and deactivated upon evacuation. Additional support equipment required will be the body mass measurement device from the Biomedical Equipment Unit (FPE 1) and the visual records storage system for storing video tapes until dumped to ground.

The experiment will commence with the activation of the TV cameras and will continue throughout the mission. It is desired that the experiment not be identified as such by the crew but become an integral part of their daily living activity on a noninterference basis. The reconfiguration of quarters or specific areas will necessitate brief exceptions to this goal.

7.4.3.1.3 Observation/Measurement Program. Primary measurements are listed in Table 7-13 under the three parameters that will be used to evaluate the interiors: physical health, work efficiency, and crew attitude. The majority of the required information will be derived from time-lapse TV recordings of the schedule, travel, and frequency patterns of the crew. Other information will be obtained by determination of man's mass/weight by utilization of a body mass measurement device, caloric food energy intake (by crew recording of food portions consumed), medical status of

Table 7-13. Observations and Measurements

Type of Measurement	Physical Health				Work Efficiency					Crew Attitude
Name of Measurement	Weight of Crewman	Food Energy Intake	H_2O Intake	Sleep Cycle Activity	Time/Area	Assigned Work Output	Unassigned Work Output	Freq. of Area Entrance/Exit	Schedule Keeping	Crew Questionnaire
Measurement Units	kg	J	cm^3	hr & min	Hr and minutes	related to task	related to activity	actual count	NA	NA
Required Accuracy	±2%	±5%	±5%	±6 min	±1 min	function of task	function of task	NA	NA	subjective
Pattern of Change	trend in one direction	trend in one direction	NA	NA	NA	observe	observe	NA	observe	NA
Reference or Control Measurement	Standard calibration weight onboard.	Meal predetermined as to calorie count (fat, carbohydrate, protein)			Related to task.	Relate to space-adjusted norm.	Relate to assigned work.	Relate to task and norm established.	Relate to preassigned schedule.	NA
Lifetime of Phenomenon	mission duration	mission duration	mission duration	mission duration	mission duration	mission duration	mission duration	mission duration	mission duration	mission duration
Duration/Measurement	30 sec.	30 sec.	30 sec.	time lapse TV of sleep period	ground station analysis	ground station analysis	ground station analysis	ground station analysis	ground station analysis	NA
Time Between Measurements	24 hours	4 hours	with meal or H_2O drink	16 hours	random	NA	NA	NA	NA	10-day cycle
Number of Measurements	3/day	3/day	3/day plus H_2O drinks	1/day	random	NA	NA	random	NA	one master form
Total Measurement Period	90 sec.	90 sec.	90 sec.	8 hours approx.	random	NA	NA	NA	NA	30 minutes
Interrupt or Vary Schedule	not critical	no	no	no	NA	NA	NA	NA	interruption is a part of assessment of crewman ability to maintain a given schedule	NA
Time from Mission Start	24 hours	start with 1st meal	start with 1st meal	start with 1st sleep cycle	24 hours	24 hours	24 hours	24 hours	24 hours	11 days

crew by sharing of biomedical experiment data, and acceptability of habitability provisions by subjective crew questionnaire. Biomedical monitoring will include muscle tone, dermal bacteria count, and cardiovascular condition. The questionnaire is a checklist type of operation that consumes a maximum of 5 minutes at the end of each work day. At the end of the mission, the answered questionnaires will form a log/diary of attitudes and accomplishments.

7.4.3.1.4 Interface, Support, and Performance Requirements. Humidity, air flow, acoustics, illumination, and temperature will be controllable within limited ranges on a programmed basis. Gravity, vibration, contamination, and radiation environmental limits will be the same as spacecraft nominal due to the nature of the investigation which requires results to be correlated to the nominal environment. The experiments will not be affected by orbit altitude, inclination, magnetic field, pointing requirements, etc. Data produced will consist of handwritten copy, tape voice recording, photographic records of paper work or experimental results, and TV time-lapse record of all habitable areas to be stored for dump to ground on command. Power required is estimated to be 165 watts.

7.4.3.1.5 Potential Role of Man. The spacecraft crew will be essential participants in the experiment, both as experimenters and as test subjects. As experimenters, the crew will be required to move partitions, false walls, changeable decors, etc., as required by the experiment time-lines and store and/or transmit records as required. As test subjects, the entire crew will be continuously participating in the experiment as part of their normal activities. They will record their activities and subjective opinions daily in the crew log and at other times as required. No specific crew skills are required other than normal preflight training on all experiment tasks. All crewmen will be equally proficient.

7.4.3.1.6 Available Background Data

a. The "Habitability" experiment in Manned Space Flight Capability, Part 1 of 2 (Biomedicine, Behavioral, Man-Machine Integration), Earth Orbital Experiment Program and Requirements Study, McDonnell-Douglas Astronautics Co.

b. The "Reconfigurable Interior Configuration and Decor," the "Habitability for Large Crews," and the "Evaluation of Design for Preventing Behavioral Degradation" experiments in Requirements Study for Biotechnology Laboratory for Manned Earth-Orbiting Missions - Phase II, McDonnell-Douglas Astronautics Company, MDC G0620, July 1970.

c. The "Volume and Layout" and the "Interior Design" experiments in Requirements Study for a Biotechnology Laboratory for Manned Earth-Orbiting Missions, NASA CR-1408, Volume I, August 1969.

d. The "Volume and Layout" and the "Interior Design" experiments in Requirements Study for a Biotechnology Laboratory for Manned Earth-Orbiting Missions, NASA CR-1409, Volume II, August 1969.

e. The "Crew Systems and Habitability" experiment in Experiment Data Book - Space Station Program, General Electric Company, EL-103, Revision C, 12 June 1970.

f. The "Habitability of Crew Quarters in Zero g" experiment in NASA Long Range Plan for Aerospace Medicine, 15 June 1969.

g. Proceedings of the Winter Study on Uses of Manned Space Flight, 1975 - 1985, NASA Science and Technology Advisory Committee for Manned Space Flight, NASA SP-196, December 1968.

7.4.3.2 Off-Duty Activities and Facilities

7.4.3.2.1 Scientific or Technical Objectives. These experiments, part of the Habitability and Proficiency Maintenance class, have as their objectives:

a. To evaluate off-duty activities and facilities for long-duration missions.

b. To validate design and provisioning requirements.

c. To maintain operational efficiency of the crew through preservation of high levels of morale and motivation.

7.4.3.2.2 Description. The experiments will require the following subjects, observers, materials, and equipment:

a. One crew member as a subject.

b. One crew member as an observer.

c. Cameras (cine, still, and/or TV) and lights.

d. Log book.

e. Questionnaires.

f. Timer.

g. Audio recorders.

7.4.3.2.3 Observation/Measurement Program. The following observations and measurements will be recorded:

a. Subjective opinions.

b. Area/compartment utilization frequency.

c. Event record.

d. Voice record.

e. Time

The measurement program will require 10 minutes per subject at 30-day intervals. Standardized questionnaires must be developed.

7.4.3.2.4 Interface, Support, and Performance Requirements. Gravitational, vibrational, contamination, atmospheric, thermal, and radiation environmental limits will be the same as spacecraft nominal due to the nature of the investigation which must be correlated to nominal spacecraft environments. Experiments will not be affected by vehicle parameters such as orbit altitude, pointing requirements, etc. The experiments are estimated to require an average of 155 watts of power, 5 kg (11 lb) of equipment, and to occupy a 0.06 m^3 (2 ft^3) volume.

7.4.3.2.5 Potential Role of Man. The crew will be essential participants as test subjects in the experiment. The entire crew will be continuously participating during their off-duty time as part of their normal activities. They will record their subjective opinions daily in the crew log and at other times as required. No specific skills are required other than normal preflight training on all experimental tasks.

7.4.3.2.6 Available Background Data:

a. The "Off-duty Activities and Facilities," and the "Computer-aided Instructions and Recreation" Experiments in Requirements Study for a Biotechnology Laboratory for Manned Earth-Orbiting Missions - Phase II, McDonnell-Douglas Astronautics Company, MDC G0620, July 1970.

b. The "Recreation" Experiment in Requirements Study for a Biotechnology Laboratory for Manned Earth-Orbiting Missions, NASA CR 1409, Volume II, August 1969.

c. The "Off-duty Activities" Experiment in NASA Long Range Plan for Aerospace Medicine, 15 June 1969.

d. Proceedings of the Winter Study on Uses of Manned Space Flight, 1975 - 1985, NASA Science and Technology Advisory Committee for Manned Space Flight, NASA SP-196, December 1968.

7.4.3.3 Skill Retention and Assessment in Long-Duration Spaceflight

7.4.3.3.1 Scientific or Technical Objectives. The remainder of the Habitability and Proficiency Maintenance class of experiments have as their objectives:

a. The identification of skills that may degrade during extended space missions.

b. The development and evaluation of methods and equipment for assessing and controlling degradation of those skills (e.g., onboard training equipments).

7.4.3.3.2 Description. Experiment-peculiar equipment such as training/refresher units and skill assessment devices will be augmented by Life Science CORE Facilities such as video cameras from the Visual Records Unit for performance of these experiments. Skills that have been judged to be critical to mission success or crew safety, that consist of complex operations to be performed under stringent time requirements, and that are infrequently used, will be evaluated using skill assessment devices for potential performance degradation. Training/refresher units for those above skills judged most likely to degrade will be evaluated for retention control. Training/refresher units may require support equipment as complex as the Human Research Centrifuge Unit (for simulation of reentry forces during a reentry control task).

7.4.3.3.3 Observation/Measurement Program. Primary measurements will consist of task completion times, error scores, and the number of refresher trials necessary to restore initial performance levels. Refresher training may require an hour per week per skill. Many measurements may be obtained by self-test techniques and require only the time of the experimental subjects. Baseline measurements will be required before the flight. It is assumed that related in-flight operational and environmental data will be simultaneously recorded to assist the evaluation of changes in performance. Any test session may be interrupted for emergency requirements, but then the problem would have to be repeated.

7.4.3.3.4 Interface, Support, and Performance Requirements. These requirements initially may be quite minimal (e.g., standard operational procedures may be monitored by video cameras in the nominal spacecraft environment for evidence of degraded skills), but may eventually vary over a wide range.

7.4.3.3.5 Potential Role of Man. Man will be an essential participant in the experiments, both as test subject and as experimenter. Required skills may vary considerably, depending on the training units necessary.

7.4.3.3.6 Available Background Data:

a. The "Skills Retention" experiment in Manned Space Flight Capability, Part 1 of 2 (Biomedicine, Behavioral, Man-Machine Integration), Earth Orbital Experiment Program and Requirements Study, McDonnell-Douglas Astronautics Co.

b. The "Skill Retention in Extended Spaceflight," the "Evaluation of Training Devices," the "Computer-Aided Instruction and Recreation," and the "Evaluation of Performance Measurement Techniques" Experiments in Requirements Study for a Biotechnology Laboratory for Manned Earth-Orbiting Missions - Phase II, McDonnell-Douglas Astronautics Co., MDC G0620, July 1970.

c. The "Influence of Flight Duration and Weightlessness on Skill Retention" Experiment in NASA Long Range Plan for Aerospace Medicine, 15 June 1969.

7.4.4 BEHAVIORAL EFFECTS AND PERFORMANCE IN ROTOGRAVITATION

7.4.4.1 Locomotion and Balancing Capabilities in Rotogravitation. In a reduced-gravity environment, the stimulus to the balancing mechanisms may be of such a low magnitude that there may be some decrease in balance effectiveness. When the low-gravity field is provided by rotation, the balancing capability will be further impaired, and extraneous forces and moments will be experienced by persons walking and climbing because of coriolis forces and the cross-coupled angular accelerations. The magnitude of these influences will be investigated by this group of experiments, part of the Behavioral Effects and Performance in Rotogravitation class of experiments.

7.4.4.1.1 Scientific or Technical Objectives. To establish the capability of man to effectively locomote and maintain postural equilibrium at various levels of centrifugation.

7.4.4.1.2 Description. These experiments will be conducted using the MSI Human Research Centrifuge and experiment-peculiar equipment as discussed below.

Subjects will be tested in a two-part standing/mobility test, with the complete test being performed at each of four centrifuge load factors (0.1, 0.2, 0.3, and 0.4 g). Test design will permit quantitative rating of test performance as a function of g-level. Testing will involve both tangential and axial excursion components, with radial components limited to marginal limb movements parallel with the subject's long-body axis.

The experiment chamber (Figure 7-8) will consist of 2.4 m^2 (26 ft^2) of cushioned surface (comparable to Ensolite) marked off in a grid of 15 × 15 cm (6 by 6 in) squares, each of whose coordinates is boldly designated alphanumerically to facilitate performance rating. The deck is curved circumferentially to render it of equal radius at all points. The subject is unrestrained but wears a protective headgear. The subject's clothing shall be marked with fluorescent lines or spots, for purpose of wide-angle motion picture evaluation of walking.

The first part of the standing/mobility test involves restricted mobility (RM); the second part unrestricted mobility (UM). The first offers the advantages of greater experiment control, easier scoring quantification, and a substantial normative and experimental data bank from previous ground-based testing. The UM relates more directly to operational mobility requirements.

The RM testing includes standing with eyes closed and walking with feet tandemly heel to toe, arms folded against the chest, and body erect.

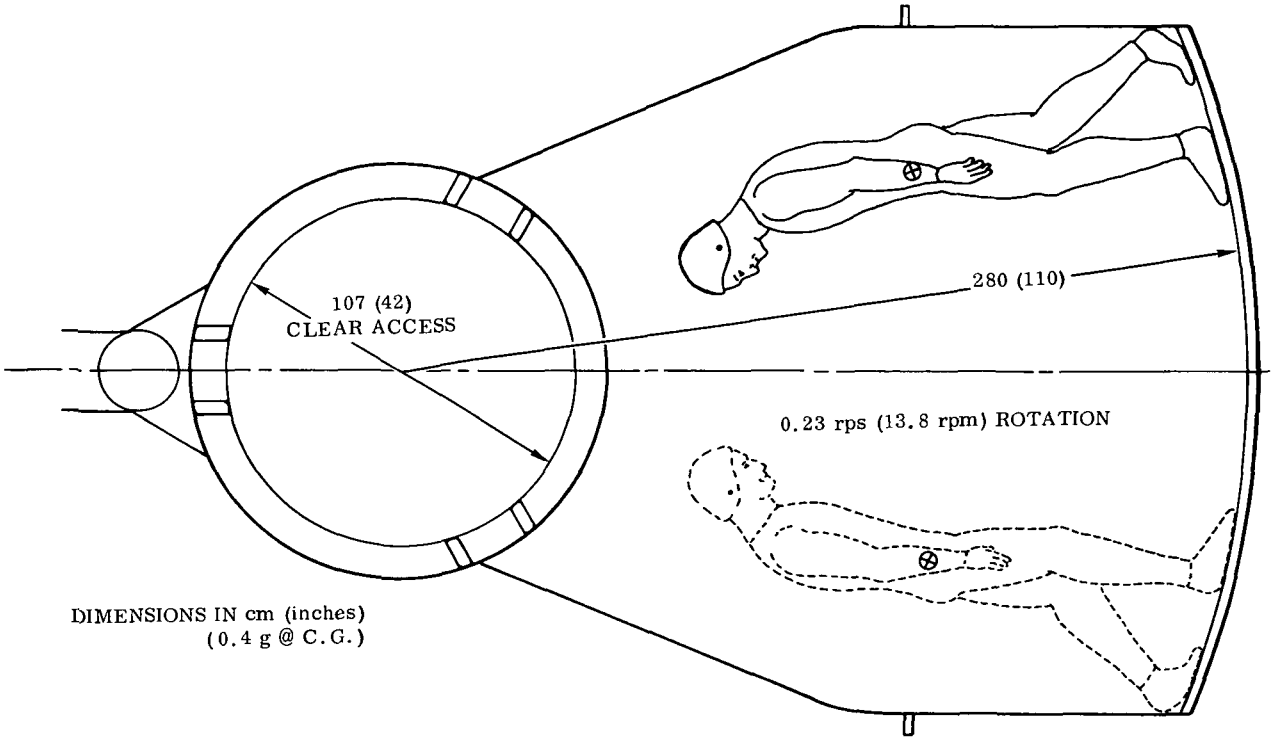


Figure 7-8. Centrifuge Experiment Chamber

UM testing requires normal walking and emergency running rates around path CC' (Figure 7-9) including intratrial reversals in mobility direction.

Experiment-peculiar equipment will consist of (1) specially marked subject clothes, (2) head gear and safety restrainss, (3) special wide-angle photographic equipment, (4) subject instrumentation, and is estimated to weigh 3.6 kg (8 lb) and be stored in a 0.06 m^3 (2 ft^3) volume.

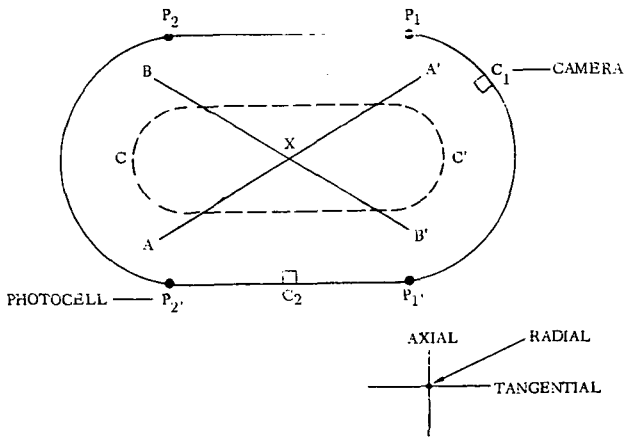


Figure 7-9. Radial View of Locomotion and Balance Test Area

7.4.4.1.3 Observation/Measurement Program. Measurements for the RM testing include total standing time and the number and direction of in-balance steps along oblique lines AA' and BB' (Figure 7-9). UM measurements include g-load, the direction of subject movement, timing of the locomotion cycle, number of required steps, subject anecdotal ratings, and gain parameters extracted from cinematographic records.

Full testing sequences (RM+UM) will be repeated at all g-levels during one testing session. Balancing of cumulative artifacts will be effected by scheduling a complete testing session eight times (each utilizing a different primary g-level permutation) during a mission for each subject, requiring a mission time-commitment of eight times 1-1/3 hours, or 11 hours/subject.

7.4.4.1.4 Interface, Support, and Performance Requirements

a. Crew Support: 4 men, 8 times per 45 days, 1-1/3 hours each time. Two men required during each operation -- one monitor and one controller. 10 hours ground training.

b. Spacecraft Support:

Digital data - 1.3 kbps, Total 6×10^8 bits/run.

Power - 1100 W-hr/operation from batteries; 250 watts at 28 Vdc from the station.

Pointing - NR.

Stability - Max. cross-product of angular velocities of $5\pi/9$ rad (100°)/sec^2 at subject's head.

Life Support - Shirtsleeve environment.

Film - 4.5 kg (10 lb)/total mission of 16 mm motion picture or video tape equivalent.

Communications - Voice comm. on Space Station intercom for operator.

Thermal Control - Provide for experiment-generated heat load of 1130 W.

7.4.4.1.5 Potential Role of Man. Man will be an essential participant in these experiments as a test subject and as an experimenter. The test subjects will require no special skills other than the normal familiarization with all experiment equipment and procedures. The experimenters will consist of a behavioral scientist, a medical doctor as a monitor, and the normal centrifuge operations personnel.

7.4.4.1.6 Available Background Data:

a. The "Walking Mobility and Balance as a Function of Rotationally Induced Inertial Support" experiment in The Orbital Research Centrifuge: Continued Design and Feasibility Study, Final Report, Convair division of General Dynamics, GDC-DCL-69-002, July 1969.

b. The "Orientation Capabilities in Zero g and Partial g" experiment in Requirements Study for a Biotechnology Laboratory for Manned Earth-Orbiting Missions – Phase II, McDonnell-Douglas Astronautics Company, MDC G0620, July 1970.

c. The "Performance in Artificial g" experiment in NASA Long Range Plan for Aerospace Medicine, 15 June 1969.

d. Artificial Gravity Experiment Definition Study, Draft Report - Part I, Advanced Manned Missions Program, Office of Manned Space Flight, April 29, 1970.

7.4.4.2 Fine Psychomotor Capabilities in Rotogravitation. In a rotating environment, head motions such as those used in monitoring widely spaced dials and switches will result in nystagmus and visual illusions. Nystagmus causes difficulty in focusing on dials or switches and the visual illusions are such that an apparent displacement of dials and switches occurs. In addition, coriolis forces acting on the hand reaching for the dials complicates operation of standard knobs and switches. The effects of the foregoing on errors and on increases in performance times will be investigated by this group of experiments, part of the Behavioral Effects and Performance in Rotogravitation class of experiments.

7.4.4.2.1 Scientific or Technical Objectives. To establish the capability of man to perform fine psychomotor tasks such as control panel operations, including tasks required in rendezvous, docking and landing maneuvers, record keeping, small parts assembly, maintenance, or repair, at various levels of artificial gravity.

7.4.4.2.2 Description. These experiments will be conducted using the MSI Human Research Centrifuge and the psychomotor consoles from the Behavioral Measurements Unit. The subjects will be tested on a battery of perceptual-motor tasks that encompasses the fundamental hand-eye abilities required to adequately perform bench tests. They will be tested over the range of artificial-g provided by the centrifuge.

The subjects will be tested facing tagentially, but not axially, since it has been determined that the former is significantly more desirable as it precludes vestibular coriolis stimuli due to pitching head movements. The subjects will repeat the battery of tests at each of four floor g-levels (0.1, 0.2, 0.3, and 0.4) during one continuous testing period.

7.4.4.2.3 Observation/Measurement Program. The measurements will be related to normative data levels established in ground laboratory baseline testing subsequent to training to an asymptotic proficiency. Four degrees of primary ordering freedom (g-sequence ascending and descending; tangential, facing with and against rotation) recommend four complete testing sessions for each subject. Each session will require approximately three hours. Each test is programmed and conducted automatically from the examiner's console. Each subject's replications will take place as consistently as is feasible at the same point in his work-rest-sleep cycle. Accurate, time-coded information concerning factors that may affect the results (prior physical activity/sleep, drug intake, etc.) will be recorded so that the data can be properly interpreted.

7.4.4.2.4 Interface, Support, and Performance Requirements. The primary requirements are those associated with the Human Research Centrifuge and the Behavioral Measurements Unit as discussed in Section 7.2. Perturbations in force field, noise level, and illumination stimuli should be minimized. Where such variations are unavoidable, effort should be made to make them quantitatively consistent during testing at all of the g levels.

a. Crew Support: 40 hours ground training and 4 men, 4 times, 3 hours each for 48 hours flight time.

b. Spacecraft Support:

 Digital data - 10 bps, 1470 bits total/run.

 Communications - Voice on Space Station intercom for operator.

 Power - 1500 W-hr/operation from batteries; 250 watts at 28 Vdc from station.

 Pointing - NR.

 Stability - Max. cross-product of angular velocities of $5\pi/9$ rad (100°)/sec^2 at subject's head.

 Life Support - Shirtsleeve environment.

 Thermal - Experiment heat load 830 watts.

7.4.4.2.5 Potential Role of Man. Man will be an essential participant in these experiments as a test subject and as an experimenter. Test subjects will require no special skills other than the normal familiarization with all experiment equipment and procedures. The experimenters will consist of a behavioral scientist, a medical doctor as a monitor, and the normal centrifuge and Behavioral Measurements Unit operational personnel.

7.4.4.2.6 Available Background Data:

a. The "Bench Task Performance as a Function of Rotationally Induced Inertial Support" experiment in The Orbital Research Centrifuge: Continued Design and Feasibility Study, Final Report, General Dynamics Convair GDC-DCL-69-002, July 1969.

b. The "Psychomotor Capabilities in Zero g and Partial g" experiment in Requirements Study for a Biotechnology Laboratory for Manned Earth-Orbiting Missions – Phase II, McDonnell-Douglas Astronautics Company, MDC G0620, July 1970.

c. The "Performance in Artificial g" experiment in NASA Long Range Plan for Aerospace Medicine, 15 June 1969.

d. IMBLMS Functional Breadboard Performance Review, Phase B-3, General Electric Company, December 1969.

e. IMBLMS FBB – Phase B-3 – Final Summary Report, General Electric Company, February 1970.

f. IMBLMS Phase B3 – Functional Breadboard, Final Summary Report, LMSC-A963878, Lockheed Missiles and Space Company, February 1970.

g. Statement of Work, IMBLMS Phase B4.

h. Artificial Gravity Experiment Definition Study, Draft Report - Part I, Advanced Manned Missions Program, Office of Manned Space Flight, April 29, 1970.

7.4.4.3 Cargo-handling and Gross Psychomotor Capabilities in Rotogravitation. In a rotating environment, coriolis and cross-coupled accelerations will act on tools put in motion by the astronaut in performing certain operations. It is necessary to determine by experimentation how these factors will affect the time and efficiency of performing standard tool operations. In addition, experiments are required to determine how these factors will affect other gross motor operations such as opening and closing doors at different locations and those which operate in different direction.

Moving objects in artificial gravity will provide force and moment inputs to the astronaut which differ appreciably from the inputs he obtained in normal gravity. For example, the gravity gradient and coriolis forces in an artificial gravity field will result in changes in weight and extraneous forces when an object is moved within the environment. In addition, cross-coupled angular accelerations will tend to rotate an object in an unnatural and undesired direction from the desired rotation initially imparted by the astronaut. The effect of these factors on astronaut performance should be established by experiments. Further experiments are required to establish the

range of weight change, coriolis forces, and the magnitude of cross-coupled angular accelerations which can be tolerated by the astronaut without adversely affecting his performance.

These experiments, the remainder of the Behavioral Effects and Performance in Rotogravitation class of experiments, will investigate these factors.

7.4.4.3.1 Scientific or Technical Objectives. To determine man's capability to move cargo and perform other gross psychomotor tasks in artificial gravity.

7.4.4.3.2 Description. These experiments will be conducted using the MSI Human Research Centrifuge, additional support equipment such as video coverage and event timers, and experiment-peculiar equipment such as test masses of varying size, shape, mass, and consistency, representative tools, experimental doors, hatches, etc.

This apparatus will be used to verify time lines, established in ground-based tests, of standard tool use in maintenance, assembly and disassembly, cargo tasks, and striking accuracy. Door and hatch configurations with various locations, controls, and opening directions will be used. Experiments will be performed with the subject facing tangentially with rotation and against rotation, and with the subject facing axially. Tests will be made with weights of 4.5, 22.5, 45 and 90 kg (10, 50, 100, and 200 lb), having volumes of 0.03, 0.11 and 0.25 m^3 (1, 4, and 9 ft^3). Measurements will be made for objects raised and lowered radially, for tangential movements with and against rotation, for combined radial and tangential movements, and rotation.

7.4.4.3.3 Observation/Measurement Program. Measurements that will be recorded consist of task performance times, number and type of errors through the use of video tapes, and subjective opinions.

7.4.4.3.4 Interface, Support, and Performance Requirements. The primary requirements are those associated with the Human Research Centrifuge as discussed in Section 7.2.

7.4.4.3.5 Potential Role of Man. Man will be an essential participant in the experiments as subject and as experimenter. As a subject, he will require no special skills other than normal familiarization with all experimental tasks. The experimenter will consist of a behavioral scientist, a medical doctor as a monitor, and the normal centrifuge operational personnel.

7.4.4.3.6 Available Background Data:

a. The "Psychomotor Capabilities in Zero g and Partial g" experiment in Requirements Study for a Biotechnology Laboratory for Manned Earth-Orbiting Missions – Phase II, McDonnell-Douglas Astronautics Company, MDC G0620, July 1970.

b. The "Performance in Artificial g" experiment in NASA Long Range Plan for Aerospace Medicine, 15 June 1969.

c. Artificial Gravity Experiment Definition Study, Draft Report - Part I, Advanced Manned Missions Program, Office of Manned Space Flight, April 29, 1970.

7.5 FPE INTERFACE, SUPPORT, AND PERFORMANCE REQUIREMENTS

This FPE requires the nominal space vehicle pressurized environment, nominal zero-g, and nominal stabilization. There are no special requirements as to ephemeris, pointing, Earth's magnetic field, orbit altitude, or orbit inclination. Experiments 7.4.5, 7.4.6, and 7.4.7 involve EVA which requires use of an airlock for access to unpressurized space. Dynamic characteristics of the Human Research Centrifuge, given in Section 7.2.1.2.2, are applicable to experiments in rotogravitation. In all other experiments, forces and torques produced will be of the same order as are incident to normal crew activities. Crew participation as experiment operators is required for all experiments. Crew members also interface with the FPE as test subjects. All experiments include documentation by motion picture and by audio tape.

The summary data presented in Table 7-14 represents, in the best judgment of NASA scientists, the overall facility and experimental requirements to accomplish a realistic experimental program, and is based on some projection of the state of the art. The rationale for selection of the summary parameters is in some instances arbitrary but has as a basis the total NASA experience and knowledge gained from prior flight and experiment definition and integration programs. The basis for each data entry is given in the notes.

7.6 POTENTIAL MODE OF OPERATION

This FPE requires long-duration stay times in the spaceflight environment for many of its experiments. The objective of many of them is the investigation of the effects of long-duration, uninterrupted spaceflight on some aspect of man's behavior. Meaningful experimental results would not be achieved by adding together the results from multiple short-duration missions.

Table 7-14. Man-System Integration FPE Summary Data

Weight, kg (lb)	2668 (5900)	Note 1
Volume, m^3 (ft^3)	31.4 (1110)	Note 1
Power, watts	3707	Note 2
Crew Skills	11. Mechanical Engineer 12. Electromechanical Technician 13. Medical Doctor 21. Behavioral Scientist	
Data Rate, bps	7 10^3	Note 2
Analog Data: hours/day	4	
frequency, MHz	4	
Logistics Up, 30-day average, kg (lb)	136 (300)	Note 3
Logistics Down, 30-day average, kg (lb)		
1st 2 years	102 (225)	Note 4
3rd year on	122 (269)	Note 5
Pointing and Stabilization	NA	
Orbit Altitude & Inclination	NA	

Unique Environment Requirements: Controlled illumination and noise levels; seclusion from visual and auditory distractions; EVA.

NOTES:
1. CORE units + FPE units + two logistic cycles of expendables.
2. 40% of CORE units total + 75% of FPE units total = normal load.
3. 1% of FPE units + 110% of expendables per 30 days of research.
4. 75% of logistics up.
5. 90% of logistics up.

The FPE also requires the full range of crew support and habitability facilities. In fact, the objective of several experiments is the evaluation of these facilities. A mode of operation which did not allow continuous crew presence at the experimental site would be useless for these experiments.

Considering flight Mode A, limited on-orbit stay time as with Space Shuttle, the experiments in Class 2, Performance Capability Assessment, and Class 4, Behavioral Effects and Performance in Rotogravitation, can be accommodated but they will be decreased in value as indices for predicting long-term phenomena. Experiments in Classes 1 and 3 cannot be accommodated in Mode A. As for flight Mode B, extended on-orbit stay time, unmanned, with periodic revisits by Shuttle, none of the experiments can be satisfactorily accommodated because man's presence is a requirement. Mode C, extended on-orbit stay time with Space Station, is preferred for all experiments because determining the long-duration effects of the spaceflight environment on man is a specific objective of this FPE.

7.7 ROLE OF MAN

The spacecraft crew will be essential participants in the experiments, both as test subjects and as experimenters. As subjects, they will directly participate by taking the required test batteries, and they will indirectly participate when being observed performing on- and off-duty activities. No special skills will be required of the subjects except for the normal preflight training on all experiment tasks. As experimenters, the crew will be required to set up the experimental hardware, adjust and maintain it as necessary, brief and debrief the test subjects, observe and record the test data, either by operation of automatic data processing equipment or by manual or voice recording, and refurbish or terminate the experiment when required.

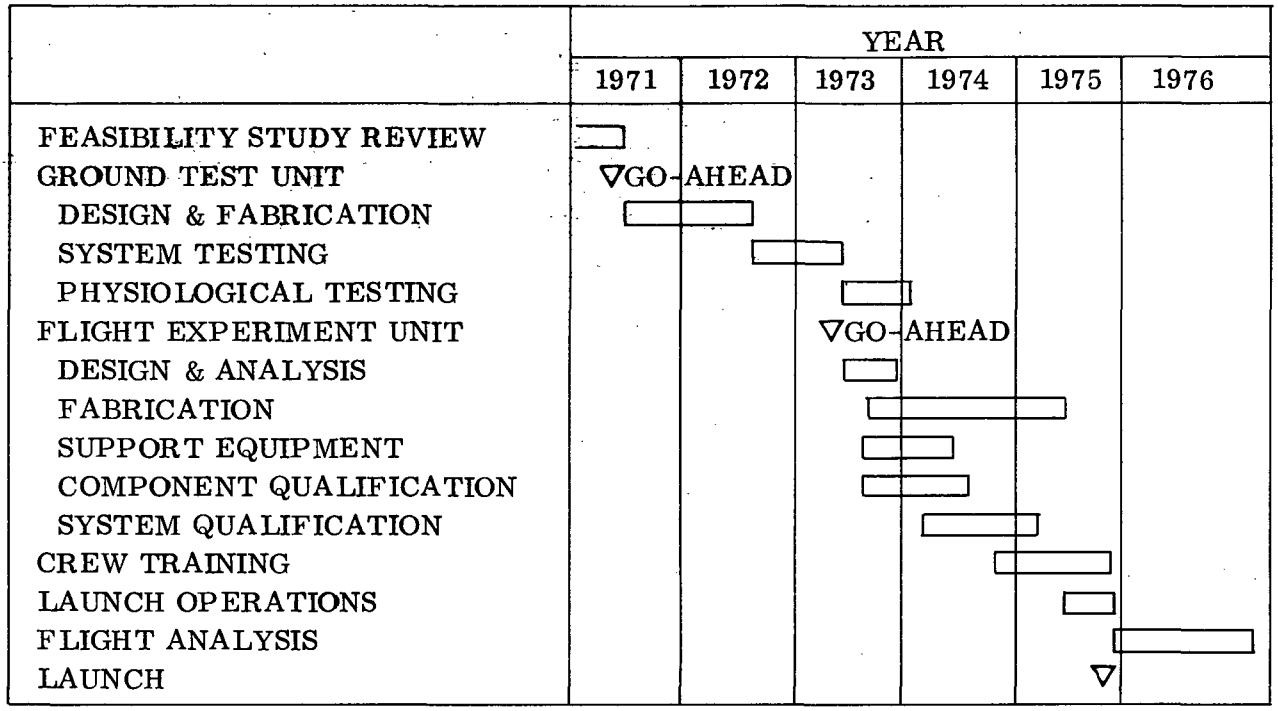
7.8 SCHEDULES

A typical example of a development schedule for the MSI experiments and equipment units is indicated in Table 7-15, the development schedule for the Human Research Centrifuge.

7.9 PRELAUNCH SUPPORT REQUIREMENTS AND GSE

No special facilities or ground support equipment above the normal requirements are anticipated for this FPE. Required prelaunch operations will be the normal training of personnel on the appropriate experimental procedures and equipment operations. Some experiments will require a preflight and postflight measurement program to provide baseline data. For these cases, the experimental tasks will be performed by each subject to determine normal values of the parameters of interest and normal fluctuations in these values.

Table 7-15. Centrifuge Development Schedule



7.10 SAFETY ANALYSIS

Table 7-16 is a safety analysis of this FPE.

7.11 AVAILABLE BACKGROUND DATA

a. Manned Space Flight Capability, Part 1 of 2 (Biomedicine, Behavioral, Man-Machine Integration), Earth Orbital Experiment Program and Requirements Study, McDonnell-Douglas Astronautics Co.

b. Requirements Study for a Biotechnology Laboratory for Manned Earth-Orbiting Missions - Phase II, McDonnel-Douglas Astronautics Co., MDC G0620, July 1970.

c. Requirements Study for a Biotechnology Laboratory for Manned Earth Orbiting Missions, NASA CR-1408, Volume I, August 1969.

d. Requirements Study for a Biotechnology Laboratory for Manned Earth Orbiting Missions, NASA CR-1409, Volume II, August 1969.

e. Experiment Data Book - Space Station Program, General Electric Company, EL-103, Revision C, 12 June 1970.

f. NASA Long Range Plan for Aerospace Medicine, 15 June 1969.

g. IMBLMS Functional Breadboard Performance Review, Phase B-3, General Electric Company, December 1969.

Table 7-16. Safety Analysis

EXPERIMENT	POTENTIAL HAZARD	SAFETY PRECAUTIONS
All	Electrical shock.	Design to preclude crew exposure to live conductors in normal operation. Provide grounding of all chassis and frames. Incorporate interlocks and discharge devices to permit maintenance and servicing. Restoration of power shall require deliberate action by crew member.
	Cuts and abrasions	Design equipment without sharp edges and corners. Design for maintenance and servicing so that crew does not have to exert high forces and torques.
	Breakage of fragile equipment	Design equipment for adequate strength. Train crew in safety requirements where some fragility is unavoidable.
7.4.1	No hazard increment due to experiment	Routine.
7.4.2	Same as 7.4.1	Same as 7.4.1.
7.4.3	Same as 7.4.1	Same as 7.4.1.
7.4.4	Same as 7.4.1	Same as 7.4.1.
7.4.5	Suit pressurization failure during EVA. Suit O_2 supply failure. Suit CO_2 removal failure.	Continuous visual monitoring. Continuous biomedical monitoring. Continuous suit atmosphere monitoring by instruments. Provide means for rapid pressurization of airlock.
7.4.6	Same as 7.4.5	Same as 7.4.5.
7.4.7	Same as 7.4.5	Same as 7.4.5.
7.4.8	Same as 7.4.1	Same as 7.4.1.
7.4.9	Same as 7.4.1	Same as 7.4.1.
7.4.10	Same as 7.4.1	Same as 7.4.1.
7.4.11	Same as 7.4.1	Same as 7.4.1.
7.4.12	Physical injury from rotating centrifuge	Continuous visual monitoring during operation. Design safety interlocks to preclude accidental starting.
7.4.13	Same as 7.4.12	Same as 7.4.12.
7.4.14	Same as 7.4.12	Same as 7.4.12.

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l. Artificial Gravity Experiment Definition Study, Draft Report - Part I, Advanced Manned Missions Program, Office of Manned Space Flight, April 29, 1970.

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